



(NASA-CR-155324) A STUDY OF WORLDWIDE  
COMMUNICATIONS MARKETS: THE RELATIONSHIP  
BETWEEN FEDERALLY SPONSORED RESEARCH AND AND  
DEVELOPMENT AND COMPETITIVENESS OF US  
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# WORLDWIDE COMMUNICATIONS SATELLITE SYSTEMS MARKETS

The Relationship Between Federally  
Sponsored Research and Development  
and the Competitiveness of U.S.  
Industry in this Market

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## A STUDY OF WORLDWIDE COMMUNICATIONS MARKETS

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Sponsored Research and Development  
and the Competitiveness of U.S.  
Industry in this Market

Prepared for  
National Aeronautics and Space Administration  
Washington, DC

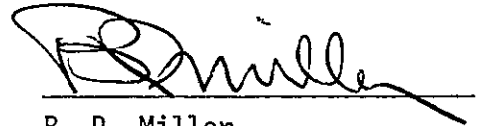
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A handwritten signature in black ink, appearing to read 'B. P. Miller', written over a horizontal line.

B. P. Miller  
Vice President

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## 1. SUMMARY AND CONCLUSIONS

The objective of this study has been to obtain answers to three questions:

1. What is the expected worldwide demand for national and regional communications through the end of this century?
2. What are the systems and technology R&D needs brought about by this demand?
3. Can the United States space communications industries effectively compete in this anticipated market without stronger R&D support from the federal government?

Many factors have been reviewed in an attempt to seek criteria for the establishment of regions or nations as potential customers for space communication systems. These include economic measures, demographic distributions, topographic variations, physical size, national dispersion, telephones available, investment credit viability and the general level of technology within the population. A major consideration is the fact that essentially all nations are subject to significant financial constraints. Consequently, some form of national investment priorities becomes necessary, and these priorities are generally perceived differently according to the factors mentioned above and also according to the personalities and interests of each nation's decision makers. Furthermore, priorities and policies are subject to change with time. As a result, fairly short-term programs are very likely to be completed, whereas long-term commitments are far less likely to be initiated and if implemented, are subject to revision and delays. These considerations relate to all forms of government program investment, including satellite communications systems.

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Clearly, nations have a basic interest in social development and economic growth. While it is difficult to define a quantitative relationship between economic prosperity and networks of communication services, the two are strongly intertwined, and nations tend to view telephone networks as essential to growth and development. As the developing nations' economies improve (indicated by an increasing GNP/capita in many nations), millions of telephones and expanded data communication systems will be installed in the coming decade with all their supporting equipment.

For developing nations, small-scale satellite communications systems, consisting of a single (or few) transponder(s) leased from an INTELSAT-type of operation to connect a few earth stations, can be implemented fairly rapidly using "off-the-shelf" hardware, which is adequately reliable, and for reasonable costs. In the main these systems will be extensions of the point-to-point trunking systems now in use. While this approach is unlikely to be optimum in performance or cost, it represents a low-risk, acceptable solution for many of today's point-to-point communications needs. U.S. industries possess the necessary technologies and experience to successfully compete with foreign sources for freeworld markets in both the space and ground segments for this kind of service. For these near-term market opportunities, there may well be federal actions or policy changes which could enhance the international competitiveness of U.S. industry; however, it does not appear that a major renewed government role in R&D would be necessary or useful to that end.

In the longer term, the communications needs, the most appropriate solutions, and the priorities for investments are much more uncertain. One of the most troubling considerations for both the potential systems suppliers

and the service users (especially emerging nations) is their ability or willingness to commit to high cost, high risk, lengthy development programs.

The long-term trend of user needs and systems applications appears to be in the direction of systems that will provide the capability for direct user-to-user communications as opposed to the trunking systems in use at the present time. Systems capable of providing direct user-to-user communications will require large numbers of small, very inexpensive earth terminals. Many of these new applications may involve the use of mobile earth terminals. The inclusion of a large number of mobile terminals in a system introduces system design problems that are significantly different from those of systems with only fixed terminals. These systems will provide the opportunity for direct user-to-user interconnection through a communications satellite, without the use of extensive ground-based trunking facilities. The technology needed for these systems that will provide direct user-to-user interconnection will differ greatly from the technology now in use for point-to-point trunking systems. This new low-cost terrestrial capability appears to be most feasible through major advances of technology in the satellite communications systems and bus performance (e.g., multiple narrow spot beams, on-board beam switching, higher precision attitude control).

These anticipated technologies unquestionably will require a large development effort including a flight test program. This by itself is not enough. A pre-operational test phase and a demonstration of operational capability are both probably needed to convince prospective buyers that the desired service can be provided reliably and on a cost-effective basis.

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In the developed nations where substantial point-to-point or trunking systems now exist, it is likely that the direct user-to-user communications satellite capability will supplement but not displace existing systems. In the developed nations the direct user-to-user capability may make possible the efficient delivery of communications services that do not now exist, or are not cost effective at present. In those nations where extensive trunking systems do not exist, it is possible that the direct user-to-user communications satellite system could be the main ingredient of a modern national communications system.

It is generally accepted that at least 10 years are required to carry a space technology program from the planning stage to the point where it is operationally useful. This study concludes that there could be a substantial world need for satellite communications systems that provide direct user-to-user connectivity by the 1990 period. These systems will incorporate many technologies that do not exist to a great extent within the U.S. space communications industry at the present time. If the hardware needed to implement such systems is to be available in a timely manner from U.S. sources, the development program must be initiated now.

This study has considered three possible sources of funding for major development programs in space communications: (1) foreign (non-U.S.), (2) U.S. private industry, and (3) federal government agencies. Based on the analyses of the facts presented in this study, it is concluded that:

- Several foreign sources (notably Canada, the European Space Agency, Japan, perhaps the USSR) are capable, interested, and are now developing new space communications systems technologies for the purpose of exploiting the markets to be derived from those new capabilities. The developing nations will be vitally interested in new systems which will meet their own

unique communications needs and permit lower communications costs. On the other hand, the developing nations must look to the industrial nations to bear the responsibility and costs of proving out the needed technologies and demonstrating the operating systems.

United States private industry, while strongly interested in pursuing the technology needs, and, of course, the ensuing market, will generally be reluctant to finance the high-cost long-term development programs for at least the following reasons.

1. They require many millions of dollars "up-front" for research and development alone.
2. There are extensive risks in many key areas including the technology (its application, performance), market opportunities a decade away in time, regulatory policy uncertainties, other factors competing for corporate investment capital.
3. The gestation period, or lag time, between R&D investment and the implementation of operational systems embodying the new technology is in excess of ten years. This long lag time, coupled with the other risks noted above, makes this an unattractive area for private investment in R&D.

A resumption of substantial federal support to space communications R&D is required if the United States is to remain competitive in this field over the long run. It is believed that within the federal framework, NASA is the logical and most appropriate federal agency to have the responsibility for satellite communications systems development programs up to the operational phase. Some of the technology to be developed may be similar to existing military systems requirements, particularly in the areas of small, low-cost fixed and mobile earth terminals. For this reason, the possibilities of cooperative development of some specific technologies, or the adaptation of existing military technology to NASA needs should be investigated. It is important that NASA be responsive to the perceived demands of the marketplace and the needs of users in the sponsorship of space communications R&D. In order to achieve this objective, other entities, such as Dept. of Commerce, HEW, OTP, private industry and communications common carriers, should play an active role in setting the goals of a development program. This participation will help NASA develop a system that will meet the needs of users in a cost-effective manner, and will help to establish a transfer mechanism for the demonstration of operational systems capability.

## 2. INTRODUCTION

There is a rising concern in government and industry in the United States that this nation is losing its position of leadership in the field of space communications, both in terms of technology advancements and as a supplier of systems hardware and designs.

Perhaps the most significant factor which has generated and fueled these concerns was the decision in 1973 for NASA to largely curtail new research and development programs in communications systems.<sup>\*,\*\*</sup> The budgetary basis and the rationale for this action are well known. In recent years, this decision has undergone reexamination in a number of studies (e.g., U.S. Department of Commerce, Office of Telecommunications Report, "Lowering Barriers to Telecommunications Growth," October 31, 1975; National Academy of Engineering, SAB 1974 Summer Study at Snowmass; NASA Task Team Report on Satellite Communications, December 1975; Federal Research and Development for Satellite Communications, Committee on Satellite Communications, National Academy of Sciences, 1977.) The main thrust of these studies was to assess the proper role of the U.S. Government in space communications research and development, for the purpose of advancing technology or providing for new systems capabilities.

This study examines the long-term anticipated communications needs throughout the world with a view toward providing answers to the following questions:

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\* NASA Release No. 73-3, "NASA Program Reductions." Also Committee Hearings on 5880, pp. 31-32.

\*\* Prepared statement of C.W. Matthews (Associate Administrator for Applications) for Hearings on 5880. NASA Authorization for Fiscal Year 1974, pp. 771-774.

- How large a market will exist for space communications outside the United States?
- What new systems or technologies will be necessary for efficient competition by U.S. industry in that market?
- How can the R&D best be performed to enhance the U.S. industrial position in the space communication marketplace?

These are formidable questions. In order to obtain answers to these questions it is necessary to assess the present state of the space communications industry, and to hypothesize a model of the needs that could be fulfilled by this industry in the future. As a result of the lag time associated with the applications of research and development, we must be concerned with user needs that are at least ten years in the future. Any assessment of specific needs a decade or more into the future tends to be speculative. However, the conclusions we are able to draw from this assessment are dependent upon trends to a greater extent than specifics, and while the specifics described may be speculative, the trends are fairly apparent. The major conclusion drawn from these trends is that there are logical and compelling reasons for renewed NASA involvement in communications satellite R&D if the United States is to remain competitive in this field over the long term.

## 2.1 Purpose

The basic purpose of this study is to address the question: Can U.S. space communications industries remain competitive throughout the remainder of this century in the worldwide marketplace (with and) without federally supported R&D? The associated question considered is: What new technologies and systems will be needed during this period and how can they be acquired?

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## 2.2 The Framework of the Problem

One of the major problems associated with this complex investigation is to formulate a logic flow that will enable the investigator to organize and convert the extensive data into meaningful information which, in turn, will lead to conclusions.

The approach taken in this analysis of space communications needs is outlined in Table 2.1. The remainder of this section sets out in more detail the major issues to be examined within this approach.

The first step was to establish some measure of the projected communications needs on a national and international basis, for various nations throughout the world for the remainder of this century. Internal, regional and global requirements were considered. This provided an estimate of the total investments and the types of services likely to be involved, as well as the degree of current sophistication of systems in existence or planned for the near term. This step was made unusually difficult because of the constantly changing nature of government planning, particularly in some of the volatile, emerging new Third World nations. A number of assumptions were necessary in this step.

The next step was the assignment of appropriate portions of the total projected communications needs to space communications systems. These estimates were based mainly upon geography, existing plant, types of service needs and availability of funds, but political issues and alternative approaches were also considered where possible.

Finally, the required technologies, both near-term and long-term, were identified based upon the estimates of communications demand and systems to meet the estimated demand. Those technologies that do not exist at the

Table 2.1 Framework of the Problem

- Basic Premise

Space communication requirements will continue to increase.

- Procedure

Examine worldwide market opportunities and resulting R&D requirements.

1. Consider total anticipated communications needs on a country-by-country basis as a function of time.
2. Estimate portions of those needs which will be best satisfied by space communications systems.
3. Estimate the technology/systems requirements for 2 above.
4. Determine the R&D requirements of 3 above.
5. Estimate the sources of R&D for 3 above, based on complexity and probable costs.
6. Relate any implied requirements for federal programs, in 5 above, to foreign activities and world market opportunities gained (lost) with (without) such federal support.

present time in the United States space communications industry are the technologies that must be developed if the United States industry is to remain competitive in the expected marketplace. Having identified the required R&D, the implications of the three possible options for development of these technologies must be considered. These options, as listed below, represent the three possible sources of the needed technology:

1. Foreign industries or governments
2. United States industries
3. United States government.

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Within the framework of our analysis, option (1) represents a trivial solution, and is only considered as a basis for evaluating current technology developments by foreign industries and governments. In reality, options (2) and (3) represent the only viable choices to maintain the competitive positions of United States industry.

### 2.3 Discussion of Issues

As will be discussed in later chapters, it is believed that the demand for improved communications in nations will continue to increase rapidly, in both the industrialized and developing regions of the world. Space communications technology will continue to compete with ground-based technology for a share of that growing market. If these premises are accepted, the following issues must then be considered.

#### 2.3.1 Need for Control or Regulation of Space Communications Resources

As additional space systems are placed in orbit (generally geosynchronous), resources such as the rf spectrum and orbital locations will become increasingly crowded. These resources are both national and international in nature. While not nonrenewable, in the same sense as fossil fuels, for example, their inefficient use could preclude their use for other purposes at a later date, or could require the expenditure of additional funds to reuse the resource.

If left solely to the user--subject to guidelines and approval by regulatory agencies (such as the FCC for U.S. DOMSAT)--systems design will continue to be biased toward the user's individual concepts and perceptions of efficient resource utilization which, in turn, is based (largely) upon their technologies and hardware "in hand" or planned, as well as on that user's perception of the market and the availability of resources to compete.

An independent view of the use of these resources, by an adequate staff of systems/technology experts, is needed for the purpose of judging and recommending to the appropriate regulatory bodies the best approaches for efficient and equitable (fair) utilization of the limited resources of rf spectrum, orbital slots and spacing. In addition to questions of allocation, the independent review should also consider the economic aspects of the request, particularly from the viewpoint of the ability of the requestor to use the resource in a timely and efficient manner.

The need for independent review and allocation of the use of these limited resources is almost self-evident. The question of institutional responsibility to perform this review is clearly a separate issue and should be the subject of further study. However, within the United States, it is clear that NASA in conjunction with the FCC has both the technical and managerial qualifications to perform this review function.

#### 2.3.2 Who Will Develop the Technology for New Applications?

In the preceding paragraphs we have advanced the proposition that the worldwide market for space communications will increase in the future. As will be discussed in the next chapter, the near-term demand for new space communications systems can probably be fulfilled with technology that is now available to the United States space communications industry. As will be shown in Chapter 4, longer range needs will require an infusion of new technology, and some of the expected technology needs are discussed in this chapter. The reader should realize that this study examines the ability of the United States space communications industry to compete in a systems market. Thus, the laboratory development of a technology is not a sufficient condition to assume competitiveness. What is required to compete in a systems

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market is the demonstration of the new technology in a systems context, in this case preferably a space communications system. Insofar as the United States is concerned, there are two potential sources for the research, development and demonstration of new space communications technology-- private industry and the federal government.

#### 2.3.2.1 Private Industry

While there are numerous examples of extensive R&D programs conducted by private industry, often requiring hundreds of millions of dollars of risk investment, space communications is unique for at least the following reasons:

1. Much of the total investment (which in itself will be at least tens of millions of dollars for even a simple space experiment) is required "up front".
2. There are few go/no-go milestones that permit sampling performance on a small scale, with small financial exposure during development. Generally, demonstration of capability in a space system is mandatory.
3. The spacecraft launch is generally a success or complete failure. A systems failure is usually not repairable (giving little data). In fact, it is often not possible to determine what has failed-- there may be no diagnostics available. It is recognized that this factor could change when the Space Shuttle and Tug become operational, and it is possible to recover as well as inject spacecraft.
4. Roughly a decade will pass between the time of the experiment proposal and the first possibility of a return on investment. Many factors that affect profitability could change in the intervening period.
5. Even if the new approach meets expectations, there is no certainty that it can be utilized operationally. Rules and regulations may then prohibit its use. With changing governments and regulatory bodies, ten years may see many revisions and redirections, especially in the developing nations.
6. Business management itself is almost certain to have undergone at least one or more reorganizations. Few corporate officers have the power to commit sizeable resources for such a long period before potential returns, especially in the face of (1) through (5) above.

For these reasons of risks and market uncertainty, new space communications technology investments may be an undesirable investment for private industry but may be a desirable investment for government.

#### 2.3.2.2 Federal Government

NASA has the charter and organization to pursue any reasonable government R&D program in space communications. While industry is generally risk averse, the federal government is (at least in theory) risk neutral. If the forecasted R&D requirements for space communications are of sufficient complexity and magnitude that private industry has a very low probability of assuming the responsibility, then the only alternative means to assure the competitiveness of the United States space communications industry in this future market calls for federal government sponsorship of the R&D.

#### 2.3.3 Marketing the New Systems

The marketing of new systems to foreign governments has not been an accepted role for the U.S. government and has traditionally been performed by U.S. industry. Because of the competitive nature of U.S. industry it is difficult for the U.S. government to intercede on behalf of a specific company in competition for foreign business. This arms-length relationship between government and industry does not exist in other nations or organizations that may compete with U.S. industry, such as the European Space Agency (ESA), Japan and U.S.S.R. Thus, superior technology is probably a necessary but not sufficient condition to ensure the long-term competitive stature of the U.S. space communications industry in foreign markets. In parallel with technology development the U.S. government should consider the economic, institutional and legislative aspects of foreign market development in order to alleviate constraints that could penalize U.S. industry in the market place.

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### 3. SPACE COMMUNICATIONS SYSTEMS AND CURRENT STATE-OF-THE-ART OF ASSOCIATED TECHNOLOGY

This chapter contains a brief description of the composition and operation of today's typical space communications systems and also provides descriptions of the state-of-the-art of current technologies in use in those systems. This information is included to provide a reference for the kinds of service and performance available through space communications, and in turn also permits a comparison with terrestrial capabilities.

#### 3.1 System Concepts

A space communications system consists of three basic segments: (1) the satellite(s), (2) a complement of earth stations, and (3) the local loops, or "tails", which connect the earth stations with the actual users of the system. Figure 3.1 depicts the total system.

##### 3.1.1 The Satellite

Communications satellites to date have been little more than unique forms of radio frequency (rf) amplifiers and repeaters, essentially transparent to the signals they pass. Transparency here means that systems to date have not used on-board processing functions to reorganize or modify the actual information received and retransmitted by the satellite. Most importantly, for the "typical" modes of operation which include single and/or multiple carrier analog and digital transmission of message, video, and data, the satellite transponders have essentially no effect on that information. (As new systems are implemented, such as very high data rate TDMA, where, for example, significant bit errors could be introduced in the initial data burst, it will be necessary to test and possibly modify present transponders

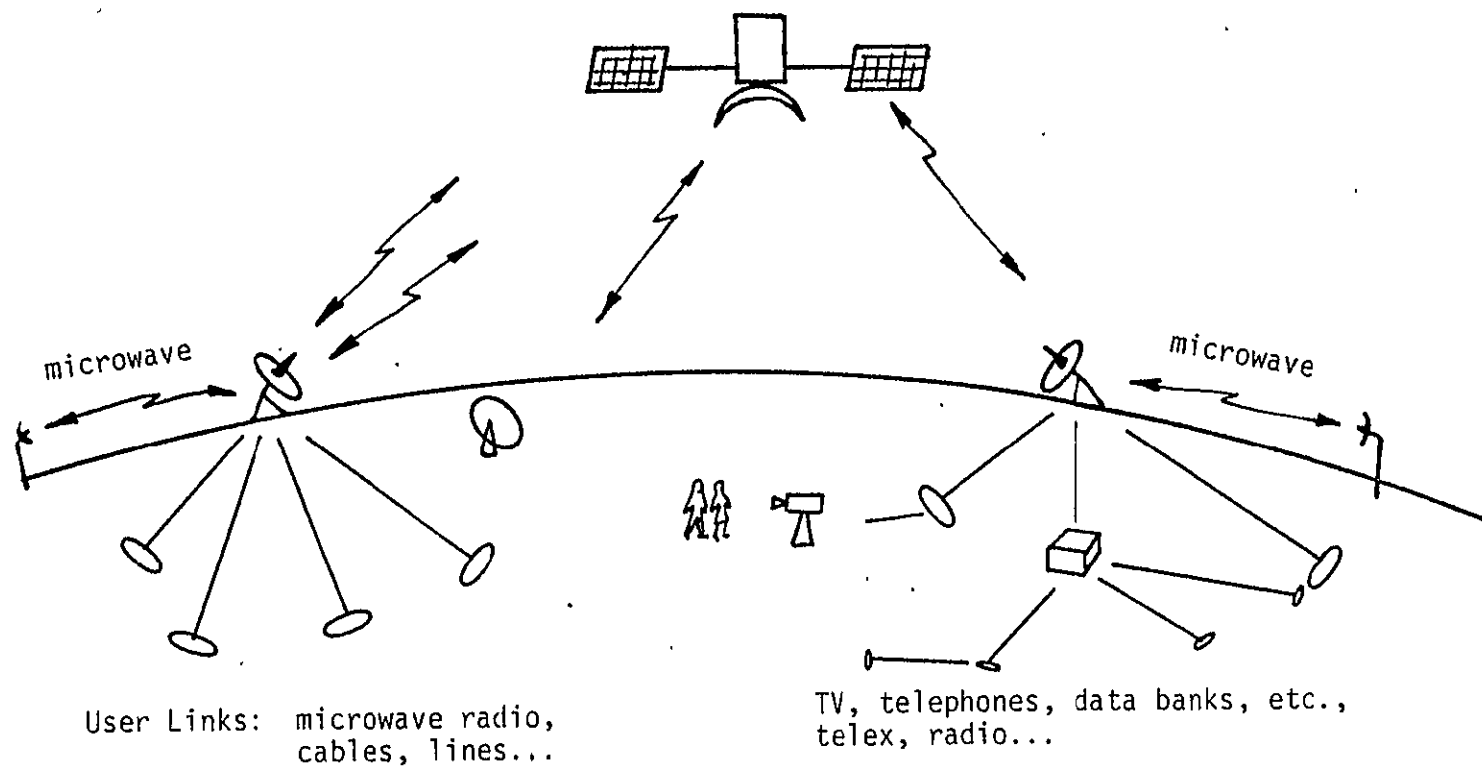


Figure 3.1 Elements of a Communications Satellite System

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to provide the prerequisite performance.) The satellite is unique in that it simultaneously "sees" and "is seen by" all earth stations within the geographic area of the system. It therefore becomes largely distance-insensitive. For example, a link between New York and California requires no more facilities or resources than one between New York and Ohio. In addition to this simultaneous observability there is potentially a substantial benefit in costs and performance for long distances since a single repeater (the satellite) replaces a very large number of terrestrial repeater stations (microwave or cable).

The sources of signal degradation and loss in the space communication system are the hardware, the propagation pathlength, and atmospheric effects. The effects of hardware are essentially fixed by the design, although some additional effects may result from aging and the space environment such as radiation damage. The propagation pathlength is a fully characterized fixed loss. Atmospheric effects are mainly signal loss, signal polarization rotation and depolarization caused by rainfall, and polarization rotation caused by the Faraday effect. These effects are strongly dependent upon the signal frequency and are well-characterized for frequencies below Ku band (12/14 GHz). Because of the strong interest in the 12/14 GHz and the 18/30 GHz bands for space communications a number of tests are being performed\* to determine the relative effects of rainfall in these bands.

To the degree it has been possible, the approach taken has been to design the space system with sufficient link margins in signal strength, and to provide polarization correcting capability (where cost effective). This has been done to ensure acceptable performance for whatever service is being provided

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\* Examples of space systems which (will) be used to conduct rain statistics measurements include ATS-6, COMSTAR, CTS and JBS.

under worst-case predicted conditions (for the projected lifetime of the system with a confidence factor in the 99+ percent range). It is this highly reliable overdesigned performance requirement coupled with the high costs of launch vehicles that makes the space segment so costly.

### 3.1.2 The Earth Stations

Earth stations in operation today cover a broad range of sizes and costs. Key factors in the costs are the antenna size, the degree of complexity of the tracking and signal correction capability, and the number of traffic channels provided. Another cost concern is the proposed location for a new earth station. In some poorly accessible geographic areas, such as isolated mountainous regions, the installation and maintenance costs may be comparable to the costs of the station equipment.

The following comments relate to earth-station performance and characteristics.

A key performance parameter is G/T which relates the gain of the receiving antenna to the receiver noise (temperature). For a given frequency, a larger antenna provides more gain (doubling the antenna diameter increases the gain by a factor of 4, or 6 dB). The noise temperature can be reduced by using various forms of cooled amplifiers. The cost of cooled amplifiers increases as the temperature decreases. The benefit derived from higher G/T is better signal and greater usable bandwidth. This leads to cost versus performance tradeoffs.

The standard INTELSAT antenna is 97 feet (29.6 meters) in diameter, and with its high complexity, capacity and redundancy, typically costs several millions of dollars to build. On the other end of the spectrum TELESAT and RCA Alascom use dishes as small as 16.4 feet (5 meters), with relatively simple receivers, but still capable of receiving excellent quality color



TV and transmitting voice grade signals. Such stations are now in the cost range of \$100,000 and costs are projected to further reduce to about the order of \$10,000 for hardware.

The rf frequency is another significant earth station parameter. At any given frequency the amount of signal power gathered is directly related to the antenna size, or gain, as mentioned above. Higher frequencies permit reduction of the antenna size for equivalent gain. Thus, there is an obvious benefit in earth station design to be derived by a shift to higher frequencies. The same benefit is available in the satellite antenna. However, the antenna design, including the reflecting dish, must be increasingly precise dimensionally to gain the full benefits of the higher frequencies. This increases the manufacturing costs.

The ability to track a satellite in position and signal polarization orientation provides another relatively clear dividing line between "low cost" and "high cost" stations. Here again there is a systems tradeoff consideration. If the satellite has close constraints on its orbital position, such as a maximum of  $\pm 0.1^\circ$  east-west and  $\pm 0.1^\circ$  north-south variations, then automatic tracking is probably not a meaningful requirement for the earth station segment. If there are many earth stations in the system the advantages of a more expensive satellite position control should prevail. Furthermore, tightly constrained position control is certain to be mandatory as orbital separation spacings become smaller. In addition, the existence of many small transmitting earth terminals with wide beams will affect satellite spacing and frequency reuse. Polarization tracking tends to be quite costly for the more complicated techniques, such as separate tracking for each feed for orthogonal signals. Smaller earth stations (5-meter class at 4/6 GHz) will usually have only a single polarization capability.

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Let us more carefully consider an important relationship between the complexities of the earth and space segments. Historically, while designers and operators were gaining confidence and experience in space communications systems, reliability was a key factor. Accordingly, there was a strong effort to minimize the communications functions performed in the spacecraft. Hence, the concept of "the rf repeater in the sky." The consequence of operational space simplicity has been the increased complexity of the earth station functions, especially in signal processing. Considering the relatively small number of earth stations involved, the costs for this increased terrestrial complexity were not a compelling factor; in fact, the alternative of a more complex reliable space segment would have been even more expensive, and perhaps not available from a technology viewpoint.

As we survey the future of space communications on a worldwide basis, from today's vantage point, it is apparent that the number of earth stations will grow manyfold. To make such growth realizable economically, the individual costs of massive numbers of earth stations must be drastically reduced. While sizeable cost reductions will be a normal effect of large volume production in a business which then attracts extensive competition, additional significant reductions can be best accomplished by reducing the complexity of earth stations. Here we can define a world community of common interest in low cost earth stations, and we can then consider the technological R&D required to develop low cost earth stations.

An examination of the total system indicates that some types of a more complex space segment will permit simplified (and low cost) earth stations. Later the specific on-board spacecraft communications functions which would simplify the earth segment will be examined. For now, it is significant to

recognize that if it is concluded that the U.S. government should pursue new space communications R&D programs to facilitate low cost earth stations, the most appropriate area for development is in a more complex space segment. This is where the R&D investment should be made.

### 3.1.3 The Terrestrial Local Loops

The local loops or "tails" are the interconnect circuits which bring the communications signals from the earth stations to and from the users. Typically these loops will consist of microwave links and cable circuits and trunks. In general, these links will be similar to any other terrestrial circuitry, where the earth station serves functions similar to toll centers and supergroup trunking centers.

The term "local loops" may be misleading, because in some instances the actual trunk circuit(s) may be as long as several hundred miles.

### 3.2 Current Trends in Satellite Telecommunications Systems Applications and User Requirements

Telecommunication traffic is traditionally divided into two distinct categories: international (national external) and national traffic (national internal). Telecommunication service delivery is provided internally either by space or terrestrial systems and is provided externally by space, terrestrial, or submarine cable systems.

The trends in telecommunication systems include space systems for external and internal traffic for either single nations or regional national groupings. In general, any current space telecommunication system must effectively couple to existing terrestrial telecommunication systems.

Various satellite communications systems are at different stages of development, from operational to conceptual. The first systems to be

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outlined are the international systems, which are of interest for national internal telecommunication use as well as for international traffic.

### 3.2.1 International Systems

#### 3.2.1.1 INTELSAT

The International Telecommunications Satellite Organization (INTELSAT) introduced operational telecommunications service on June 28, 1965, with INTELSAT I (Early Bird) located over the Atlantic Ocean.

The telecommunications institutions of 94 nations (see Table 3.1) hold investment shares in the organization. Operational satellites are located over the Atlantic, Pacific and Indian Oceans, providing interconnectivities through some 112 earth stations and 140 receiving/transmitting antennas located in more than 75 different countries\* (see Figure 3.2). The standard INTELSAT antenna is 97 feet (29.6 meters) in diameter. Some member nations do not possess their own earth station but have access to one through terrestrial links to facilities in other countries.\*\* Some nations own nonstandard antennas and as a consequence are susceptible to extra billing charges for service delivery.

The space segment of the system is owned in common by the member nations, but each nation contracts for, establishes and operates its own earth station and ancillary equipment.

Satellites are launched for INTELSAT by NASA on a cost reimbursable basis established by the Communications Satellite Act of 1962. INTELSAT I provided 240 voice circuits or one TV channel per satellite and introduced live intercontinental commercial television. INTELSAT IV-A, introduced early in 1975,

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\*All figures are as of April 30, 1976.

\*\*The earth station at Tanum, Sweden is jointly owned by Sweden, Denmark, Finland and Norway.

Table 3.1  
Member Nations of INTELSAT

Afghanistan	Iceland	Qatar
Algeria	India	Saudi Arabia
Argentina	Indonesia	Senegal
Australia	Iran	Singapore
Austria	Iraq	South Africa
Bangladesh	Ireland	Spain
Barbados	Israel	Sri Lanka,
Belgium	Italy	Republic of
Bolivia	Ivory Coast	Sudan
Brazil	Jamaica	Sweden
Cameroon	Japan	Switzerland
Canada	Jordan	Syrian Arab
Central African	Kenya	Republic
Republic	Korea, Republic of	Tanzania
Chile	Kuwait	Thailand
China, Republic of	Lebanon	Trinidad and
Columbia	Liechtenstein	Tobago
Costa Rica	Luxembourg	Tunisia
Cyprus	Malagasy	Turkey
Denmark	Republic	Uganda
Dominican	Malaysia	United Arab
Republic	Mauritania	Emirates
Ecuador	Mexico	United Arab
Ethiopia	Monaco	Republic
Finland	Morocco	United
France	Netherlands	Kingdom
Gabon	New Zealand	United States
Germany, Federal	Nicaragua	Vatican City
Republic of	Nigeria	State
Ghana	Norway	Venezuela
Greece	Oman	Vietnam
Guatemala	Pakistan	Yemen Arab
Haiti	Peru	Republic
	Philippines	Yugoslavia
	Portugal	Zaire,
		Republic of
		Zambia

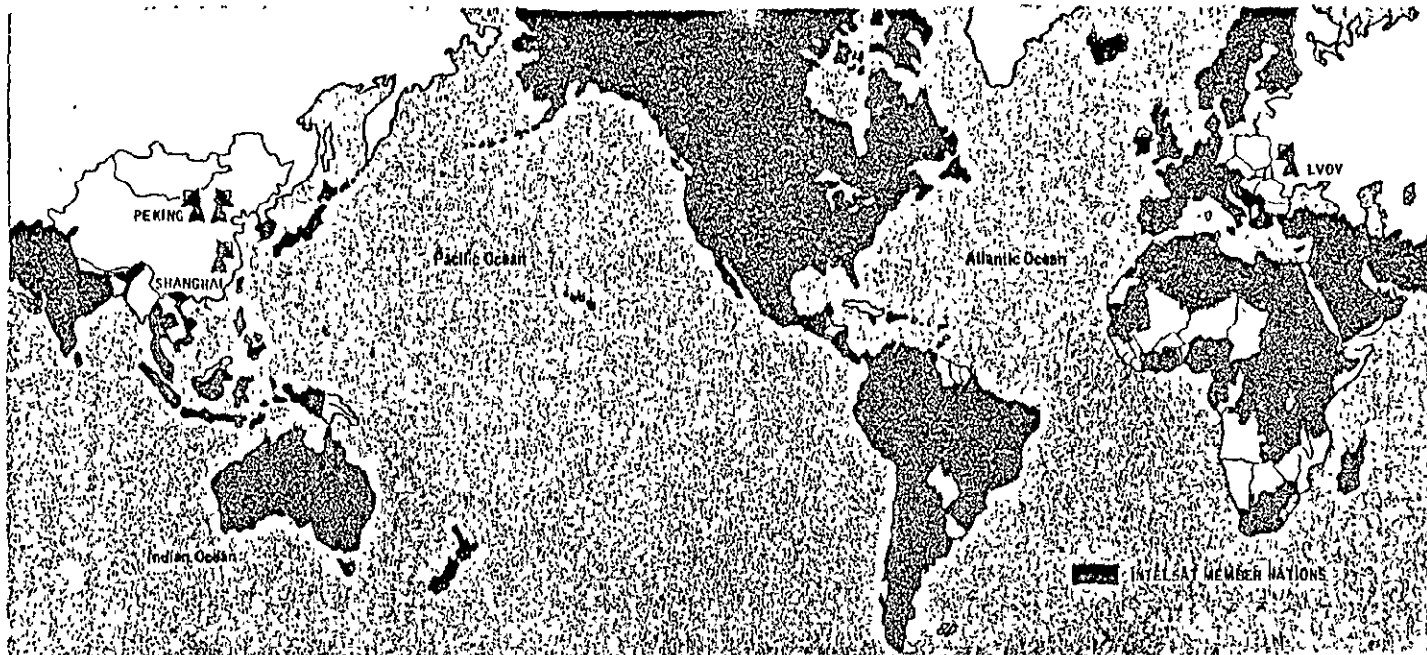


Figure 3.2 INTELSAT Member Nations

(Source: Aviation Week and Space Technology, December 15, 1975)

has a capacity of about 8000 voice circuits operating in the 4/6 GHz frequency bands. Aeronutronic Ford will build INTELSAT V, possibly for launch in 1978-1980. This system will employ two frequency bands, 4/6 GHz and 11/14 GHz, to cope with the expected fifteenfold increase in global communications traffic between 1986 and 1993. The six largest traffic members of INTELSAT will build new earth stations to operate at 11/14 GHz, and continued construction at 6/4 GHz is expected. The communications requirements for INTELSAT V are not known.

Early Bird (INTELSAT I) employed a hard limiting transponder and frequency division multiple access (FDMA). Only two earth stations could access the satellite simultaneously if channel capacity was to be maintained. As the number of earth stations grew and a variety of traffic patterns developed which varied from heavy to light, the need for better accessing and control was recognized.

By the time INTELSAT IV was launched, multiple access equipment, coding and modulation equipment, demand assignment and switching (DASS) equipment were developed to accommodate heavy/medium channel assigned traffic and light demand assigned traffic. These were interconnected as required to nationally different signaling and switching systems according to CCITT standards. The demand access method implemented is called Single-Channel-Per-Carrier, Pulse Code Modulation, Multiple Access, and Demand Assigned Equipment or SPADE. Twenty SPADE-equipped stations are in the Atlantic region. INTELSAT IV consists of 12 independent transponders, eight of which transmit via spot beam or global beams. The remaining four, one of which is a SPADE transponder, transmit globally.

In the mid-1980s, INTELSAT plans to introduce some form of time division multiplexing and in the early 1980s must make decisions for INTELSAT VI

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frequency choice (6/4, 11/14, 20/30 GHz) and frequency reuse policy (space and/or polarization diversity). This planning must proceed with the knowledge of the Space Shuttle and its possible impact on the availability of the currently used Atlas-Centaur launch vehicle. It also appears possible that INTELSAT's planning may have to take into account the existence of the U.S.S.R.'s stationary satellites and their ability to operate with smaller antennas.

The INTELSAT system has expanded considerably over time. Individual satellite costs have grown from \$4 million to \$13.5 million, launch costs from \$3.7 million to \$16 million; but the investment per circuit year of capacity has decreased from \$15,300 to \$500. The world's investment in communications satellites and earth stations exceeds \$1 billion and annual circuit revenues exceed \$500 million. Late in 1976, the 94 member nations of INTELSAT are expected to authorize the organization's capitalization to \$1 billion to finance the fifth series of global commercial satellites (INTELSAT V).

INTELSAT, in a 1974 decision, enhanced to some degree the creation of regional or internal national systems by offering via INTELSAT III over the Indian Ocean, pre-emptible transponder time with a five-year lease at \$1.90 per minute or about \$1 million per annum. Thus, a relatively modest investment in earth stations can bring space communications to any region. In August 1974, GTE International received a \$9.6 million contract from Algeria, to provide the first internal communications network using INTELSAT, with a set of 14 earth stations. Algeria has been followed by Nigeria, Norway, Brazil, Spain and in an interim step, Sudan, Columbia, Zaire and Chile.\*

It is clear that INTELSAT has been responsive to international traffic needs, reducing costs whenever possible by the application and development of

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\* Brazil and Spain use a regular service from INTELSAT, not the pre-emptible service. Chile uses only a few circuits of a transponder.



technique and technology. In the heavy traffic Atlantic region, the SPADE system demand assignment multiple access (DAMA) control, together with signalling control for high quality communication, has been introduced. This is a PCM-PSK (pulse code modulation--phase shift keyings) system. Recent evaluations of FM and single-channel-per-carrier (SCPS) operation view FM as more effective for smaller receiving terminals, 3 to 30 feet (approximately 1 to 10 meters) in diameter.\* INTELSAT demonstrates the international commercial capacity for continued technological and technique development. This has been oriented to progressive and expanding demand by a well-defined commercial market. It has also been demonstrated that demand increases in developing nations by virtue of the availability of the system. Jordan established an earth station in December 1971 with prior telephone contract with the United States of 3 to 4 thousand minutes per annum. This reached 71 thousand minutes by 1973. Brazil progressed under similar circumstances from 422 thousand minutes in 1968 to 4.7 million minutes by 1973.\*\*

INTELSAT's operation, expansion and general commercial well-being is a major force in exploiting technique and technology for its specific applications. It further serves as a tangible example of the international satellite telecommunications potential. Clearly, INTELSAT usage in the leased mode to individual nations provides a practical demonstration to national users of the advantages and disadvantages of internal telecommunications.

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\* Conference Proceedings, World Telecommunications Forum Technical Symposium, Geneva, 6-8 October 1975, FM the "New" single channel per carrier technique 1.4.3.1.

\*\* Telecommunications Euro-Global edition, Vol. 9, No. 12, December 1975, p. 31.

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INTELSAT space-proven technology also provides an international basis for other competent national design and fabrication groups to develop techniques and technology for operational systems (other than point-to-point, or point-to-multipoint).

INTELSAT, with its 94 member nations, provides direct service to only 64 countries out of a possible 189, so that to date much of the world either sees no need, or is reluctant to join INTELSAT. If the U.S.S.R. plans are implemented, essentially duplicating INTELSAT, a most vigorous exploitation of the current state of the art in space communications may result, although the technological competition may be politically motivated.

INTELSAT has agreed, with the assistance of the Secretary General of the U.N., to facilitate communication priorities for periods not to exceed 90 days during emergency peacekeeping and disaster relief. INTELSAT will also establish formal relations with the International Telecommunications Union, International Civil Aviation Organization and Intergovernmental Maritime Consultative Organization.

INTELSAT has generated annual U.S. industry revenues averaging \$200 million while cumulative U.S. industry revenues have exceeded \$1.3 billion.

INTELSAT's 1976 approved R&D budget is \$5.56 million. Of this, \$3.37 million will go to Comsat Labs, the remainder to international contracts.

#### 3.2.1.2 U.S.S.R.

A second international system which could offer competition to INTELSAT is Stationar. The U.S.S.R. has disclosed plans to install seven Stationar satellites over the Atlantic, Pacific and Indian Oceans. These will operate in the 6/4 GHz frequency band but will be capable of operating with a smaller antenna (30 feet, or approximately 10 meters, diameter) and cheaper earth

terminals similar to those used in Telesat and RCA domestic systems. Satellite launches are planned for 1978 to 1980. The U.S.S.R. is not a member of INTELSAT, although there is an earth station in Moscow and a SPADE earth station at Lvov which participate in the system. Statsionar I would become operational about the same time as INTELSAT V.

It is conjectured that stations, through U.S.S.R. sponsorship, would provide interconnections among Bulgaria, Cuba, Czechoslovakia, German Democratic Republic (East Germany), Hungary, Mongolia, Poland, Rumania and possibly Albania, but not other centrally planned economy countries such as Peoples Republic of China, Democratic Republic of Vietnam and the Democratic Republic of Korea because of differing political influences.

None of the centrally planned economy countries participate fully in INTELSAT largely because of U.S. domination during INTELSAT's formation. Thus the Statsionar system would provide an essential service for the countries cited. It would provide other nations with an alternative to INTELSAT for internal interconnection for their communications, with cheaper ground stations (antenna costs are about 5 percent of INTELSAT's) due to the increased power of this system.

It is also possible that the U.S.S.R., as a political policy, may attempt to lure nations away from INTELSAT by a variety of financial propositions or enticements. Presumably, if this happened, ground stations would have to conform with Russian requirements, making competition by U.S. industry difficult. However, many questions about this system still have to be resolved. These concern radiation interference with the Franco-German Symphonie and Indonesia's satellites, as well as with INTELSAT. Meetings are in progress or have been planned to resolve any possible problems of this nature.

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The outcome of this U.S.S.R. plan could affect the earth terminal market available to the U.S. industry in the future, yet no measure of that effect is now possible.

The two systems, INTELSAT and Statsionar, both primarily conceived for international telecommunications traffic, appear to be competitive for the future and are capable of providing connectivities for national internal communications.

### 3.2.2 Regional Systems

A regional system is one that provides telecommunications connectivities among a number of different nations, but does not extend into global international connectivities. A number of such systems are in process, either as studies, plans or additions to expanding terrestrial networks (including short haul submarine cable), and will be outlined in some detail later in this section.

The use of telecommunication satellites for regional applications appears to be an integral part of future plans in regions where competition by U.S. space industries presently appears favorable. However, some areas outside of Europe will first require the development of telephone and other traditional backbone types of networks before satellite systems can be used effectively. Furthermore, as with other space systems, regional system development requires considerable capital; however, such development is also potentially beneficial to the region as a whole in that it is expected to promote considerable economic development.

Regional satellite systems responsive to current requirements seem to be within the current state-of-the-art and a number of industrial organizations have the capability to provide the necessary hardware.

Opportunities for the U.S. telecommunications industry appear evident. Where the space segment is open to competition, as in the Arab League, one U.S. representative, Hughes Aircraft Corporation, is in direct competition with two European consortia.

Regional satellite system development appears to be planned for regions which seem to foresee an improved economic climate developing as a result of interconnectivity. It is not clear, from economics or from history, how dependent economic progress is on rapid, almost instantaneous communication traffic. However, one can state that the need for speed is more obvious in an economic climate of highly developed competition, such as exists in the industrialized nations.

The regional systems tend to consolidate based on some commonality component, i.e., all Arabs, all Africans, all Spanish-speaking, but such labels do not accommodate the diversity of national characteristics involved.

Regional programs appear to be directed toward quality regional communication fabrication and service substructures, using technology transfer, educational aid and the general methodologies of the technically advanced countries. This seems to indicate, for example, a future trend perhaps of satellite earth station manufacture within the regional boundaries using indigenous industries, and a consequent decline in marketing opportunities available to U.S. industry.

Opposition to regional systems is voiced in some quarters because of satellite susceptibility to actions such as jamming, interference and displacement, possibly as an aggressive act at some level, against the region being served. In these instances, cable is thought to be more appropriate.

The economics of INTELSAT may be adversely affected by the introduction of regional systems because of a siphoning-off of interregional traffic.

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This will be especially significant if intersatellite, interregional communications evolve.

An additional impact to the U.S. space industry will also occur when other nations begin to compete with NASA for launch capabilities. An example of this form of competition is the European ARIANE launch vehicle now in development.

The regional systems proposed will now be outlined together with their objectives and any known problems associated with their implementation will be described.

#### 3.2.2.1 Arab League

The 20 member states of the Arab League (see Table 3.2) plus Cyprus, Ethiopia, Greece, Malta and Turkey, a group with common socio-economic affiliations and interests, seeks to establish a regional telecommunications network as a consequence of a boom in economic development. The Arab League countries (18 out of 20) have agreed upon a dedicated communications satellite network for the Arab community. The agreement was signed on April 12, 1976 with the appointment of a technical committee to determine requirements and define specifications for the system. Although the participating governments will contribute to the program, it is their intent to operate it as a commercial enterprise with the objective of repaying the investments by member nations within several years. The operational user organization is yet to be established; however, the headquarters for the administration of the system is expected to be Saudi Arabia since it will be the largest contributor.

The total system has been studied and evaluated by the Arab League, the Arab Telecommunication Union (ATU), the Arab States Broadcasting Union (ASBU),

Table 3.2 Arab League States

Algeria	Sultanate of Oman
Bahrain	Syria
Iraq	Tunisia
Jordan	United Arab Emirates
Kuwait	Abu Dhabi
Lebanon	Dubai
Libya	Sharjah
Mauritania	Ras-Al-Khaimah
Morocco	Ajman
Peoples Republic of Yemen	Umm Al-Qaiwain
Qatar	Fujeirah
Saudi Arabia	United Arab Republic
Somalia	Yemen Arab Republic
Sudan	

the Permanent Frequency Committee for the Gulf Area and the Sultanate of Oman. The Arab countries initially requested a UNDP/ITU (United Nations Development Program, New York) feasibility study/preinvestment survey. This, after consultation with the Arab Fund for Economic and Social Development (AFESD) Kuwait, and with the involvement of UNESCO, resulted in approval in Cairo in September 1975 of a Master Plan and a two-year detailed preinvestment study.

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The actual study was undertaken by experts chosen by the ITU who collected comprehensive data relating to telecommunications usage, national economic parameters, telecommunications infrastructure and national economic and telecommunications development plans. Technical data was obtained from published sources and from visits to the various countries. A data bank is now established on an ITU computer. The ITU data bank will be updated and made available for assistance in network development planning and economic studies for national network developments, within the region. Included in the studies have been preliminary sections on satellite communications, which can be expanded into general requirements if requested. Preinvestment studies still to be done will enable the governments concerned to identify the investment needs for the services sought and also to identify personnel, educational and training requirements. This may result in a consolidated Regional Telecommunications Training Institute to implement, maintain and operate the system.

The degree of expansion is visualized as growing from the current two million telephone subscribers of the Arab League to fourteen million by 1990, requiring, at current value, an investment of about \$18 billion in telephone plant and equipment.\*

Competition to sell the communication satellite system to the Arab League is among ARCOMSAT and MESH, which are two European consortia, and Hughes Aircraft Company. The ARCOMSAT consortium is headed by Messerschmidt-Boelkow-Blohm GmbH of Germany together with AEG-Telefunken, and proposes use

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\* Conference Proceedings World Telecommunication Forum, Technical Symposium, Geneva, 6-8 October 1975, p. 1.2.1.1. et seq.



of SYMPHONIE-proven technology to handle the telephone/telex and TV distribution. The MESH consortium headed by Hawker Siddeley Dynamics includes Matra, Erno, Saab-Scania and Aeritalia.

The substantial oil-based wealth of the Middle East offers opportunities for communications development both in terms of systems and manufacturing facilities. The United Arab Republic has introduced special legislation to allow and encourage this type of investment. On the other hand, the Arab League and its associated nations do not yet clearly favor a satellite system either as a primary or secondary future communication system. The required specifications have, however, been established for these systems for the next decade.

#### 3.2.2.2 U.S.S.R.

In June 1975, the U.S.S.R. submitted plans to the International Frequency Registration Board of the ITU for three satellite launchings, Stat-sionar 1, 2 and 3. Of these, Statsionar 2 will offer interconnecting services between Europe and the western U.S.S.R. for telephone, telegraph, phototele-graph, sound and TV services. The plans are being studied by various agencies for possible signal interference with existing or proposed systems.\* Presum-ably if any interference problems are satisfactorily resolved, this regional interconnection will become operational and will most likely operate with fairly inexpensive receiving terminals.

The Soviet Union, as a prime world power and as source and focus of political and economic ideology, seeks to expand its overseas telecommuni-cations activity as widely as possible. Also, the U.S.S.R. has established

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\* Aviation Week and Space Technology, September 22, 1975.

an international organization called Intersputnik headquartered in Moscow, with Bulgaria, Cuba, Czechoslovakia, East Germany, Hungary, Mongolia, Poland and Rumania as members. The organization is being established in three stages. First, experiments with member earth stations using links provided by the U.S.S.R. will be performed. Next, communication channels on members' satellites will be leased. Commercial operation will follow when considered to be economically advisable.

### 3.2.2.3 Africa

The continent of Africa, composed of 54 nations, has been the subject of a recent study. This resulted in recommendations for a Pan-African Telecommunication Network (PANAFTEL) which will initially be terrestrial. This work was performed by the ITU under sponsorship of the United Nations Development Program (UNDP), and included both technical and investment study results.

In general, existing African telecommunication networks are felt to be neither as well developed nor as profitable as the general economic development in Africa would indicate. The average telephone density in Africa is 1 per 100 inhabitants compared to a world average of 8.6 per 100 inhabitants and a U.S. average of 65.47 per 100 inhabitants. In some of the developing African countries, the average is only 0.57 telephones per 100 inhabitants.

To further its socio-economic development, Africa is in urgent need of an efficient, modern telecommunication network with standardized tariffs. This should be responsive to and consistent with the growing urbanization and government policies. An integrated homogeneous network would provide telephone, telex, telegraph and television services. The initial system recommended is a combination of coaxial cable and radio relay systems, which is seen as being appropriate to the future development of national networks.

The initial PANAFTEL network will be a minimum essential network. With its development and the expected associated growth in traffic, the need for a complementary network is seen.

During the next decade, at the earliest, it is estimated that about one-third to one-half of the total regional African traffic would best be routed via satellite, which has also been suggested by ITU for implementation.

Development is proceeding in two phases, one in the period 1970-1978 and the other in the 1975-1990 period. The anticipated network will consist of about 20,000 km of transmission links and 18 switching centers, requiring an investment of about \$100 million; it will serve about 30 of the 54 African nations. The links will be medium to high capacity microwave relays. Traffic forecasting is very difficult since no reliable base traffic data exists for telephones, television or radio broadcasting in this area of the world. Financing has primarily been secured from ADB (Asian Development Bank) and IBRD (International Bank for Reconstruction and Development). The extensive systems planning and centralized funding should insure that the network will be both technically and financially sound.

#### 3.2.2.4 Europe

In 1968 the European community, in recognition of the future significance of space applications, set itself two basic goals for 1980. These goals are to develop appropriate satellite expertise and technology in Europe and to implement a regional satellite telecommunications system under the direction of the European Space Agency (ESA), then the European Space Research

Organization (ESRO). This agency is the representative of ten nations\* (France, West Germany, United Kingdom, Italy, Belgium, Sweden, Netherlands, Switzerland, Spain and Denmark). It provides programs for contracted research and development and manufacturing opportunities for its member nations. The combined ESA and national budgets (see Figure 3.3) for 1976 for satellite applications development is approximately \$800 million, which is an increase of 30 percent over the 1975 expenditures.\*\*

ESA, during the period 1977-1980, plans to complete two major programs, ARIANE and SPACELAB, and to launch five geostationary satellites, GEOS, OTS, METEOSAT, MAROTS and AEROSAT.\*\*\* This should establish the agency's technical competence and initiate an era of European operational satellites and space launching systems.

Objectives of ESA beyond 1980 will be to produce inexpensive satellites and to improve both the efficiency of ESA and of European industry.

ESA visualizes not only the extension of its capabilities to technical management of the space segment but, through cost effectiveness and credibility demonstrations, the establishment of an effective and competitive European industrial structure as well. This would be responsive to European and Third World application satellites requirements and would establish a working relationship with international organizations. A key objective in world markets appears to be to create demonstrations for users who would then

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\* As of December 31, 1975, Ireland has applied for membership in ESA but until ratification of the new conventions, Ireland will continue as an observer.

\*\* Reasons influencing this increase are the European inflation rate and price variations due to currency exchange fluctuations.

\*\*\* ARIANE has a \$156 million budget for 1976.

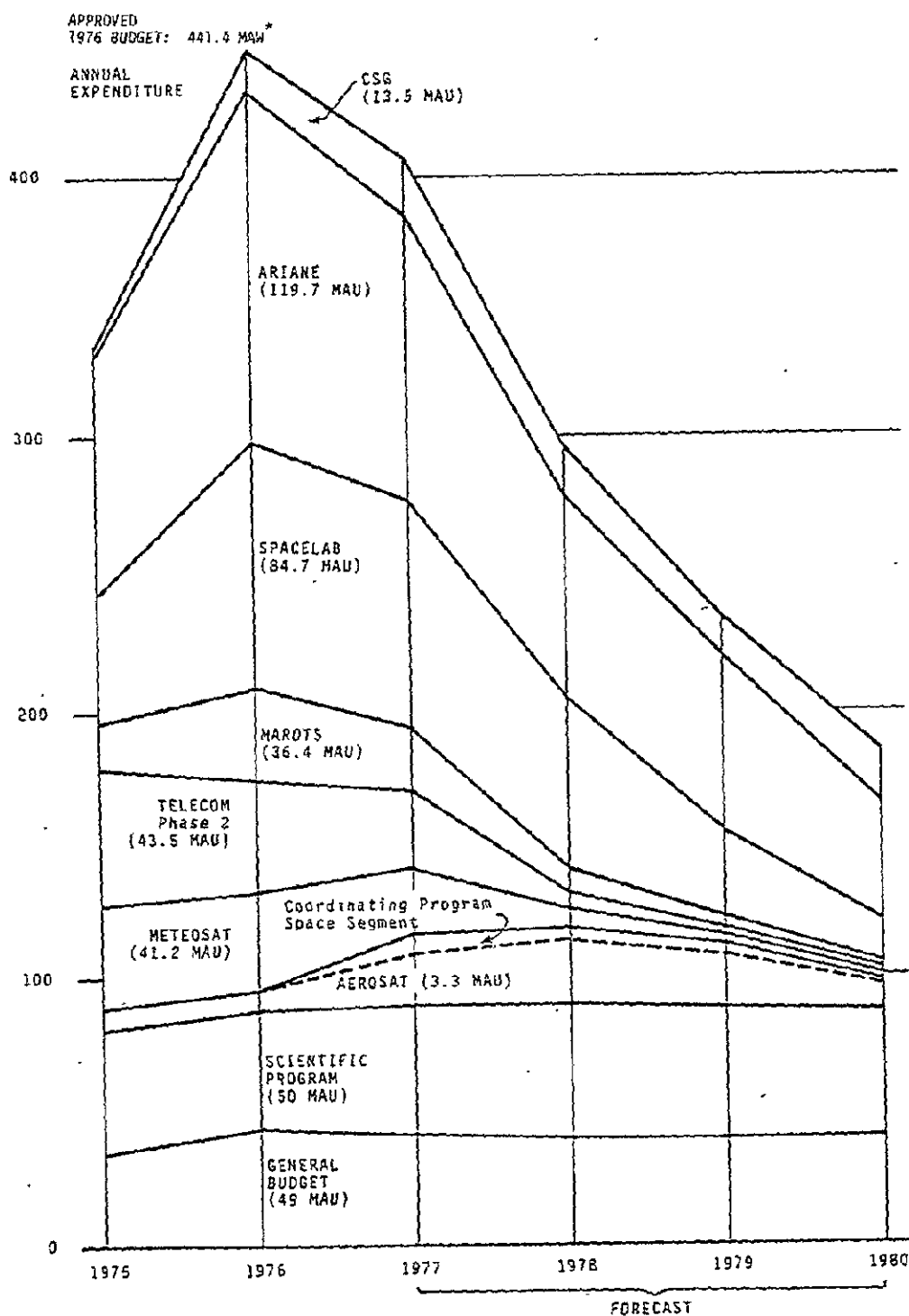


Figure 3.3 European Space Agency's Budget  
(Source: Aviation Week and Space Technology, March 15, 1976)

\*MAU is one million accounting units. As of the date of this figure 1AU = \$1.30(U.S.).

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manage their own system applications. ESA would also seek to facilitate international financing for commercial applications, and make maximum use of available financing by integrating facilities, programs and technical competence.

The program to produce and operate the European Communication Satellite (ECS) is proceeding in three phases:<sup>\*</sup> one, the operational system concept; two, the space qualification of technologies in the Orbital Test Satellite (OTS); and three, the creation of the ECS. The ECS will distribute TV to the members of the European Broadcasting Union (EBU) by an exchange of Eurovision programs. This will reduce the complexity of distribution by terrestrial lines and will enable real-time TV service to members currently without it, such as Cyprus, Eire, North Africa, Iceland, Israel and Lebanon.

In addition, as a result of collaboration between the European Conference of Post and Telecommunication Administrations (CEPT) and the EBU, the ECS system will carry a sizable fraction of the long distance intra-European telecommunication traffic. In general this fraction is based on an a priori assumption that ECS will be competitive with terrestrial lines for switching centers separated by more than 800 km.

During the progress of the work at ESA on the European regional systems, a number of studies have been made to identify possible missions which may be filled either by the direct use of technology being developed for the basic mission, or by minimal adaptation of the technology. Overall, the

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<sup>\*</sup>Conference Proceedings World Telecommunications Forum, Geneva, October 6-8, 1975, Technical and Political Problems of European Space Research 3.1.4.1.

possible missions can be characterized as "Specialized Communications", and may be listed as:\*

- Communications to areas of difficult access (e.g., North Sea oil rigs)
- Data network communications
- Computer communications
- Remote printing
- Teleconference service
- Videophone service
- Electronic mail service.

Numerous communication applications are being conceived by Messerschmidt-Boelkow-Blohm (MBB), in particular a high performance spacecraft bus which incorporates unique features that can be accommodated by the ARIANE launch vehicle to be launched in 1980 from Kourou/Giana.

For regional communication systems, MBB sees potential markets in the Arab League, India, Latin America, and plans to give Brazil the SYMPHONIE prototype model. Since SYMPHONIE was launched by NASA it cannot compete in international commercial service markets, as this is prohibited by INTELSAT agreement.\*\*

Although first-generation satellites are not yet defined in detail, it is possible to summarize at this time the principal features of the projected system:

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\* Conference Proceedings World Telecommunications Forum, Technical Symposium, Geneva, October 6-8, 1975, A Possible Evolution of the ECS 2.4.7.1.

\*\* Aviation Week and Space Technology, September 22, 1975, p. 19.

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- One or two earth stations per country are envisaged
- Operation in the 11 and 14 GHz frequency bands
- High-speed digital transmission of telephone signals
- Time-division multiple access (TDMA)
- Digital speech interpolation (DSI)
- Frequency reuse by polarization discrimination
- EUROBEAM satellite antennas covering the CEPT/EBU region
- Narrow-beam antennas (SPOTBEAM) to cover the high-density traffic zones
- Earth stations with 49- to 59-foot (15- to 18-meter) antennas, 2 kW transmitters and uncooled low-noise parametric-amplifier receivers.

The spacecraft itself will be a three-axis stabilized vehicle using an inertia wheel. The choice of this design, rather than the spinning configuration, was made in view of its greater efficiency in terms of payload capability and the increased flexibility in adapting the vehicle to a given mission.

#### 3.2.2.5 South America

Following preliminary studies in Spanish-speaking South American countries, a UNDP project concerning feasibility planning and preinvestment was undertaken by UNESCO in association with the ITU. The participating countries were Argentina, Bolivia, Columbia, Chile, Ecuador, Paraguay, Peru, Uruguay and Venezuela. The basic concept of the study was to investigate the use of telecommunications including satellites for educational and cultural development. The results of the study are not yet available.



### 3.2.2.6 Southeast Asia

A proposal for Southeast Asia was under consideration to interlink national television services and to provide national educational television services. The status of this proposal is not known.\*

### 3.2.2.7 Central America

The countries of Central America (Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica) under COMTELCA, a Technical Regional Telecommunications Commission, have established an integrated terrestrial communication transmission and switching system, with substantial intercapital city links plus additional links to Mexico and Panama. The installations have been supplied by Nippon Electric, Mitsui and Company, Ltd. (Guatemala, Honduras and Nicaragua) and by L. M. Ericsson, with additional aid from Space Standards SPA of Italy. Financed by the Central American Bank for Economic Integration, this has provided a modern backbone network for telephone, telex, telegraph and TV distribution. The program has also established a service training and maintenance organization--the Central American Telecommunications Institute. At present there is no identified requirement for satellite communications in this regional system.

### 3.2.3 National Systems

A national system is, by definition, limited to communications among earth stations located within that nation's boundaries. At this time (1976) only two possibilities for such service exist: either to lease circuits from an INTELSAT operational satellite, or to finance and implement a dedicated system as either a commercial or (quasi) government venture. Such a national system presents commercial opportunities in space segments, earth

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\* UNESCO Report No. 66--Reports and Papers on Mass Communications--A Guide to Satellite Communications.

terminals and associated equipment and peripherals for all international manufacturers.

Within a country an individual user may lease or purchase systems services from a common carrier or lease transponders of the satellite service to interface with his own earth terminals; or as occurs when the satellite merely provides supplementary links to an existing system, the user has no interface related uniquely to the satellite operations.

We will first briefly review the INTELSAT contracts for national service. In the subsequent discussion of independent systems, a number of specific satellites are now well-characterized. This provides an opportunity to describe the significant technology details which are representative of the current state-of-the-art, and also provides guidance on future needs and forthcoming technology advances.

#### 3.2.3.1 INTELSAT Contracts

Algeria will extend telephone and telex traffic among 14 earth stations using 36-foot (10.9-meter) antennas in the remote desert areas, using one INTELSAT transponder on pre-emptible service basis. Service was inaugurated in March 1975. Earth stations were to be completed by 1976. The earth station contract was given to GTE International at \$9.6 million, and FM program audio duplexers were provided by COASTCOM of Concord, California. A satellite solution seems ideal and an INTELSAT link is clearly the most cost effective method at present. An economic expansion away from the traditional northern centers of population, which are well served by communications, is occurring. The satellite system is less costly, faster to install and easier to maintain in the desert than a terrestrial equivalent.

Brazil, while presently using one INTELSAT transponder, desires an independent satellite system and is evaluating proposals for BRAZILSAT submitted by several competitors. The Brazilian plan calls for three satellites, each with a capacity of 7,000 to 8,000 one-way telephone connections and four point-to-point TV channels.\* Yet Brazil is currently burdened with \$22 billion of foreign debt acquired with the intention of financing rapid growth of its economy, expecting exports would then pay off the debt. Now, however, approximately one-third of Brazil's exports are used to pay off interest on that debt.\*\* Thus, it seems reasonable to assume that Brazil is politically committed to seeking the advantages of internal satellite communications, yet economic prudence may curtail the desire. A politically and economically expedient interim solution would be to use INTELSAT and a minimum investment in ground stations.

The Federation of Malaysia, with its geographically separated West Malaysia and its eastern components Sabah and Sarawak on Borneo, leased a transponder in July 1975 for a period of five years. Two ground stations will be constructed for its domestic system, one at Kuantan, its INTELSAT site, using a 43.6-foot (13-meter) parabolic antenna. A contract, valued at \$3.3 million, was awarded to Nippon Electric Company.

Zaire has been approved for a transponder to transmit to 19 ground stations which have been contracted for with Collins Radio (April 30, 1976). Zaire has a powerful radio transmitter and a government operated TV broadcasting station in its capital, Kinshasa; yet, its distribution system is such that there are only 0.9 radio receivers and 0.3 television receivers per

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\* Aviation Week and Space Technology, July 12, 1976.

\*\* Economist, December 27, 1976, p. 22.

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1,000 people.\* Similar figures for the United States are 1,695 and 472, respectively. Rapid expansion of TV and communications functions to the population through an INTELSAT link is the objective of the new system.

Chile will lease a one-half transponder for five years starting October 1, 1976 to establish a communication link between its capital city, Santiago, and its southern region, Punta Arenas. Southern Chile is mountainous, swept by high winds and is extremely cold, a region more accessible via satellite than by terrestrial means. Chile planned in 1975 to construct a nonstandard earth station at Punta Arenas, and in 1976 at Longovilo, the site of its INTELSAT antenna close to Santiago. Its proposed leasing arrangement would allow easier extension of the government's television network into southern Chile.

Norway will lease a one-half transponder for North Sea oil rigs, using 42-foot (12.8-meter) mainland terminals and 32-foot (9.7-meter) antennas for the rigs. This off-shore application is well suited to satellite connectivity. Norway also programmed nonstandard earth stations at Lund, Frigg in 1975 and at Ekofisk, Statfjord in 1976, presumably for this application, since Norway shares the Swedish INTELSAT station at Tanum.

Nigeria is presently using a pre-emptible transponder with a five-year lease from INTELSAT and plans to lease a second transponder in mid-1976. The total ground complex for two transponders will consist of twelve transmit/receive ground stations for television, telephone and data. Nigeria's applications can be conjectured as being the expansion of radio and television distribution and possible assistance in furthering economic

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\* World Communications, Unipub/The Unesco Press, 1975, p. 128.

development and control in raw materials such as columbite, tin, coal and petroleum.

In addition, Nigeria has ordered a \$150 million tethered-balloon telecommunications system from TCOM, Corp., a Westinghouse Electric subsidiary. The system is comprised of five terminals, each equipped with two tethered balloons (one as a backup).\*

Columbia has been approved to lease one-fourth of a transponder from INTELSAT for a link from Bogota to San Andres, and is in the process of formulating a domestic satellite system. The country consists of three divergent topographic areas: coastal plains adjacent to the Caribbean and the Pacific, a west coastal region crossed by three parallel ranges of the Andes, and an eastern region of northern plains and southern jungle.

About 80 percent of the Colombian population relies on radio for news, and the educational and cultural usage of radio is established through Radio Sutatenza, which provides graded courses in the early morning and evening for rural adults. About 84 percent of the population lives where television coverage is available and a developing relay network extends this coverage to the mountain-shadowed areas. The state controlled Inra-vision (Instituto Nacional de Radio y Television) provides education programs to half a million students, plus evening courses in literacy and basic school subjects. Presumably Columbia will seek to explore the potential in satellite usage for expanding their current programming rapidly and inexpensively to the remainder of their population.

Leasing of INTELSAT capacity generally is complementary to existing telecommunications systems. Usage, or selection, as briefly discussed above,

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\* Aviation Week and Space Technology, March 29, 1975.

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is specialized to each nation's integrated objectives. No general rules seem to emerge.

### 3.2.3.2 Independent Satellite Systems

#### U.S.S.R.

The U.S.S.R. satellite Molniya I was launched in April 1965 to provide experimental and commercial telephone calls between Moscow and Vladivostok (about 7,000 km) as well as experimental monochrome TV (see Table 3.3). In addition, color TV transmission experiments using SECAM-III between Moscow and Paris (Pleumeur-Bolou earth station) were undertaken.

In 1971, Molniya II was launched to provide color and monochrome TV to the Orbita network plus sound broadcasts and multidemand telephone throughout the U.S.S.R. Molniya satellites are launched into highly eccentric orbits to provide full U.S.S.R. coverage. Molniya I consists of several L-band satellites, while Molniya II is slowly replacing these with C-band for the Orbita-2 ground stations. In 1974, there were some 45 earth stations in the system.

The Orbita terrestrial distribution system has been in operation since 1967 for the distribution of color TV programs from Moscow to stations within a range of 3,000 to 7,000 km. The transmission also includes newspaper pages and centrally broadcast programs other than TV, such as meteorological charts. In 1970, 65 percent of the population had TV reception and by 1975 it is estimated about 82 to 85 percent will be served.

Statsionar 1, the first synchronous satellite, is used for TV broadcasting from Gus-Khrustalnyi near Moscow to community reception antennas beyond the Urals, in Siberia and in the extreme north of the U.S.S.R.

Statsionar 3, similar to 1, will provide complete coverage in U.S.S.R. territory except for the extreme north and Kamchatka. For both satellites,

Table 3.3 U.S.S.R. Satellites

U.S.S.R. Satellites	Comparable INTELSAT Satellite and Cost*	1974 Launches	1975 Launches
Molniya 1	INTELSAT II \$20 M	2	3
2	III \$23.5 M	3	3
3	IV \$30 M	1	3
1-5	II \$20 M	1	-
Statsionar (4 Kosmos 775)	CTS \$60 M	-	2
* Estimated recurring cost			

earth to space transmission is at 6.2 GHz, with the downlink at 714 MHz.

There is little detailed data available on the technologies employed in U.S.S.R. space hardware. One very significant technology employed in the Molniya system is the first use in space of a gymballed momentum wheel for attitude control.

#### Canada

Canada has a domestic satellite system developed under the aegis of the Canadian Satellite Corporation known as Telesat Canada, owned jointly by the Canadian Government, the Canadian common carriers and the general public. The system consists of three C-band (6-4 GHz) ANIK satellites, two operational and one an in-orbit spare, launched in November 1972, April 1973 and May 1975 respectively. Current ANIK satellites (and WESTAR) are the so-called oblate dual-spinners built by Hughes (see Figure 3.4). The

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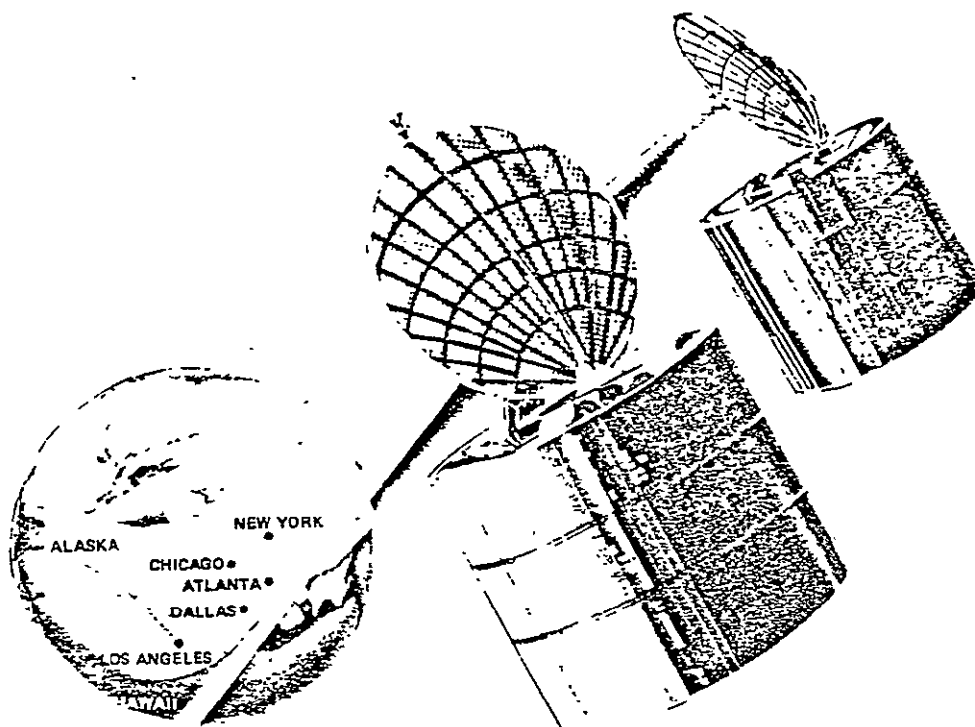


Figure 3.4 WESTAR, An Oblate Dual-Spinner

antenna is de-spun using an rf rotary joint. Satellite capacity is 5,000 telephone circuits or 12 color TV channels with full eclipse capability for 10 channels. The ground network consists of 50 to 70 earth stations, antenna size ranging from 42 feet (12.8 meters) for heavy route traffic to 10 feet (3 meters) for portable stations, with a total of six different classes of earth stations being used. Within 3 to 4 years it is planned to have about 200 earth stations operational.

This conventionally designed system provides domestic telephone service augmentation, network television distribution and overseas telephone traffic. The current system has an estimated operating life of seven years.



More ANIKs are being developed including a capability of operations at 12-14 GHz and 4-6 GHz with 12-14 GHz. A new Telesat Canada communications satellite will be delivered in February 1978 by RCA at a contracted cost of \$19.1 million. It will provide twelve channels at 4-6 GHz and four channels at 12-14 GHz. The satellite will be three-axis stabilized similar to RCA's SATCOM. The contract with RCA also provides for telemetry, tracking and other ground support equipment for the Telesat ground facility at Allan Park, Ontario.

In a joint project with NASA and ESA, the Canadian Government launched (January 1976) the Communications Technology Satellite (CTS). Many of the technologies being tested in CTS will apply to space systems in the 1980s (see Table 3.4).

CTS combines ESA lightweight solar arrays providing more than 1 kW of power, NASA's 200-Watt travelling wave tube and a three-axis stabilization system with antenna pointing accuracies of  $\pm 0.2$  deg in pitch and roll and  $\pm 1$  deg in yaw. The spacecraft has two gymballed, fully steerable 28-inch (71-cm.) diameter antennas. Transmitted power can be as high as 59 dbw, compared to 53 dbw for ATS-6. The satellite cost is now estimated to be well in excess of the earlier stated \$61.9 million and launch cost (DELTA) \$10.8 million, for the five-year developmental program.

The operational test program objectives include color TV transmissions at 12 GHz to small low-cost ground terminals, uplink TV transmissions at 14 GHz from small terminals, radio broadcasts to very small terminals, two-way TV and voice, wide band and data relay experiments. This provides valuable data for TV direct broadcast planning. The high power available will allow the use of low-cost ground antennas as small as 32 inches (81 cm.) in diameter.

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Table 3.4 Advanced Technology Unit Design\*

Unit	Key Features	Design Source
200-Watt TWT	D.C. to RF efficiency 40%	U.S.A. (Litton TWT/TRW Power Supply)
20-Watt TWT	Lightweight, high gain high efficiency	E.S.T.E.C. (Thompson-CSF)
Parametric Amplifier	Solid state pump, 300°K noise temperature	E.S.T.E.C. (GTE, Milan)
Field Effect Transistor Amplifier	Low power consumption, solid state (lightweight replacement for driver TWT)	CANADA (CRC, Ottawa)
High Power Multiplexing Network	Low insertion loss, 250 Watt C.W. power handling capability	CANADA (RCA Limited)
Wideband Frequency Translator	Low noise design with integrated low profile input and output filters	CANADA (RCA Limited)
Graphic Fibre Epoxy	Ultra lightweight with coefficient of thermal expansion equivalent to Invar	CANADA (RCA Limited)

\* V. O'Donovan, G. Lo, A. Bell and L. Braun, "Design of a 14/12 GHz Transponder for the Communications Technology Satellite", AIAA Paper No. 72-734, CASI/AIAA Meeting, Ottawa, July 1972.

The experiments will be performed over two years in medicine, education and technology and will certainly further the state-of-the-art in space-proven operations.

Both the U.S.S.R. and Canada face similar problems in attempting to provide uniform telecommunications services to all of their population. Each has vast, largely inhospitable territories to service, populated by both high density and quite low density regions in which considerable economic development activity is underway (especially Northern Canada's oil fields). Each nation's telecommunication structures respond effectively to the high density requirements and the multicultural and multilanguage needs found therein. Satellite telecommunications is ideally suited to economically extending these services to the low density population regions, and to fulfilling each nation's political and economic objectives.

The policy of the Canadian government is that participation in earth station installation must be either Canadian or a Canadian affiliate, whenever possible. Earth stations contracts let have been approximately as follows:

RCA Ltd.	\$12.1 million
Raytheon Canada Ltd.	3.2 million
Ford Aeronutronic of Canada	1.8 million
Raytheon Canada Ltd.	4.4 million
University of Saskatchewan	<u>0.7 million</u>
Total	<u>\$22.2 million</u>

Telesat leased from Hughes Aircraft Company five portable 10-foot (3-meter) antennas for \$0.36 million for two years. Northern Electric Company Ltd. of Canada is expected to manufacture similar ground stations under

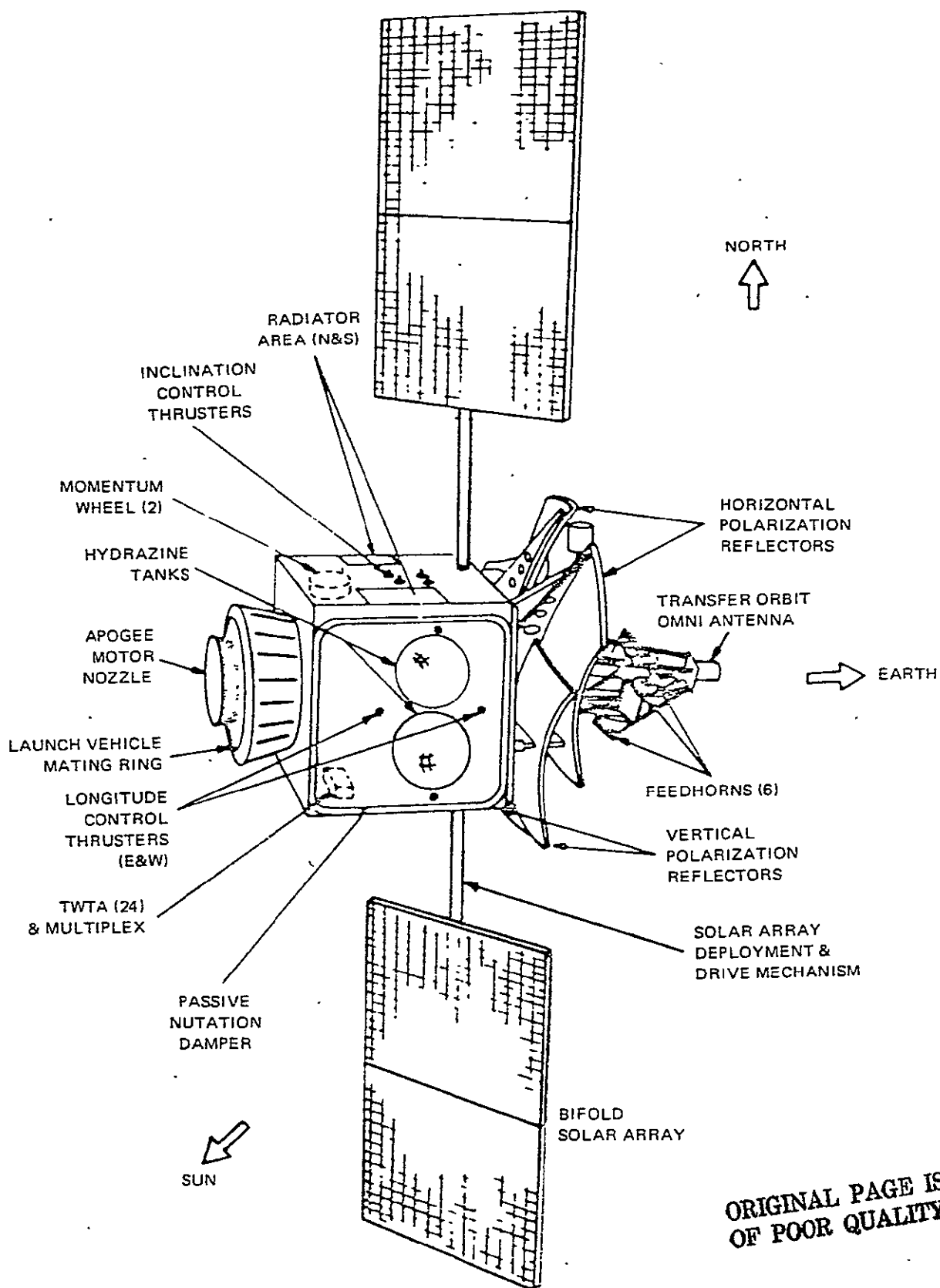
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license from Hughes at a cost of about \$20,000 apiece. Telesat receives annual revenues of about \$28 million from systems users, considerably more than had been expected.

The Canadian Department of Communications (CDOC) is concerned with satellite telecommunications planning, Canadian industrial supplies, technology research, systems research and development, and service requirements for domestic communications. Their studies have been concerned with the expansion of communications to remote areas, broadcasting by the Canadian Broadcasting Corporation in the 1980s, low cost community and individual broadcast receivers at 2.5 GHz and 12 GHz, and UHF systems for low demand voice and data transmissions. As described earlier, Telesat has also ordered a new satellite for a 1978 launch to provide experimental services at 12/14 GHz as well as commercial services in the 4/6 GHz band. Studies have also investigated the appropriate method for integrating satellite and terrestrial systems for long distance telecommunications traffic. In addition, Canada participates in the international programs of AEROSAT, INMARSAT and INTELSAT.

#### United States

The first United States domestic satellite service was provided by Western Union's WESTAR 1, launched in April 1974. As with ANIK, WESTAR utilizes several earlier INTELSAT technologies, and provides 12-36 MHz channels of a single linear polarization. The RCA SATCOM system (first launched in December 1975) provided a number of significant advances in state-of-the-art technologies. This 3-axis stabilized spacecraft (see Figure 3.5) provides 24 channels at 6/4 GHz using linear orthogonal polarization for frequency reuse, and because of ultra-light components (including graphite-fiber-epoxy



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Figure 3.5 RCA Satcom Component Locations

filters replacing conventional invar) could be launched on the new Delta 3914 (also a commercially sponsored development undertaken by McDonnell Douglas and RCA Corp.). The RCA SATCOM is interesting to consider in that it provides a yardstick to measure private industry's willingness (and perhaps limits) to invest in fairly long-term and sizable space development programs.

Comsat has leased the COMSTAR satellites to ATT to serve switched telephone traffic interconnecting four ATT and two GTE switching centers. COMSTAR (first launched in May 1976) also provides 24 channels at 6/4 GHz by means of orthogonal polarization and is largely based upon INTELSAT IV technology. COMSTAR contains a 19/28 GHz beacon package to permit rain statistics experiments in that band.

A listing of current North American communications satellites is contained in Table 3.5. (ATS-6 is not listed.) Another proposed U.S. commercial system is Satellite Business Systems, SBS, a joint venture planned (recently approved by the FCC) by IBM, COMSAT and Aetna Insurance Company. SBS is dedicated to digital transmission for data including computer-to-computer service, voice and image traffic.

The proposed SBS system will utilize 8-channel satellites at 12/14 GHz, with each channel capable of 41 megabits/sec in a time division multiple access, demand assignment mode (TDMA/DA), through a large number of small dedicated earth stations. The SBS timetable anticipates service inauguration in 1979. The total estimated cost of the program by 1986 is over \$400 million.

#### Indonesia

Indonesia through its national telecommunications organization PERUMTEL has chosen a 12-channel ANIK type satellite, designated Palapa, with a first launch in late 1976 and the second in 1977, to operate with 40 earth stations.

Table 3.5 North American Communications Satellites

Satellite	Launch Date	Manufacturer	Operator	Description
Anik 1	November 1972	Hughes	Telesat Canada	First domestic satellite (Canada)
Anik 2	April 1973	Hughes	Telesat Canada	Second Canadian satellite
Westar 1	April 1974	Hughes	Western Union	First U.S. domestic satellite
Westar 2	October 1974	Hughes	Western Union	Second Western Union satellite
Anik 3	May 1975	Hughes	Telesat Canada	'Growth' satellite for Telesat Canada
RCA Satcom 1	December 1975	RCA	RCA	24 channels
C.T.S.	January 1976	S.P.A.R.	Canadian Gov't.	Most powerful broadcast satellite
Marisat 1	February 1976	Hughes	Comsat General	Ship to shore (Atlantic)
RCA Satcom 2	March 1976	RCA	RCA	Second RCA satellite
Comstar A	May 1976	Hughes	A.T.&T.	Begins Bell Satellite System
Marisat A, B,C	February, June, October 1976	Hughes	Comsat General	Ship to shore (Pacific)
Comstar B	July 1976	Hughes	A.T.&T	Second Bell Satellite

INTELSAT, managed by the Communications Satellite Corporation (Comsat), has launched international satellites since April 1965.

(Source: The New York Times, May 13, 1976)

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Hughes Aircraft International has a \$71 million contract to produce the two satellites and ten earth stations, \$23.6 million for the satellites, \$47.5 million for nine stations and a master control. Of the remaining 30 earth stations, ITT received a contract to provide 15 for \$30 million, and Ford Aeronutronic was contracted for the remaining 15.

Application plans are to use a portion of capacity (5,000 duplex telephone circuits or 12 TV channels) for telephone and TV transmissions, a national radio network, data traffic and leases to other nations. One transponder will be available for military use.

Indonesia, which extends for about 3,000 miles along the equator, is made up of 3,000 islands, the most important being Java, Sumatra, Kalimantan (Borneo) and Sulawesi (Celebes). The islands are mountainous and have many volcanoes. Java contains about 67 percent of the population and the capital city is Djakarta, where about five million people live. Indonesia is an exporter of both petroleum and natural gas and is economically assisted by United States military funds.

Radio coverage throughout the republic is quite reasonable, about 114 receivers per 1,000 people. Television coverage is, however, limited to Java, Sumatra and South Sulawesi. Factors limiting this coverage are the mountainous regions and the absence of electricity outside of towns and major villages.

At a recent meeting of the InterGovernmental Group for Indonesia (IGGI), \$400 million was pledged in bilateral aid for fiscal year 1975-76, \$500 million was pledged by semiconcessional loans from international organizations and \$1.1 billion is being sought outside of IGGI. U.S. aid is about \$60 million and the Export-Import Bank will provide substantial additional funding.



Indonesia has a very impressive list, perhaps the most impressive of any developing country, of major projects, with a total value of \$15 to \$20 billion.\*

Indonesia has many characteristics suited to satellite telecommunications development--the geographic dispersion, mountainous terrain, extensive economic development and the sources of financing for both the ground and satellite structures.

#### The Philippines

The Philippine archipelago is a group of eleven large islands and 7,000 smaller islands spread over some 1,200 miles of ocean. Good quality radio and television coverage and distribution is difficult to achieve economically other than via satellite connectivities. Currently the number of receivers per 1,000 people is 42 and 11, respectively, for radio and television. To provide extensive coverage would presumably require many earth stations and the Philippines have expressed interest in leasing services on Indonesia's independent satellite.

#### Iran

Iran's government has signed a letter of understanding with ATT, American Bell International and USAF (ESD) to plan and engineer a telecommunication system which involves foreign military sales agreements between the United States and Iran. The satellite system is expected to require two or three satellites and a network of several hundred earth stations at a total cost of about \$1 billion.

Currently, updating of the ground network has been initiated with an award of a \$600 million contract to GTE International, part of which provides

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\* Commerce Today, August 4, 1975, p. 40.

for the establishment of an Iranian industry to produce telephone switching equipment. This is, to date, the largest single contract awarded for telecommunications development.

Iran has also contracted with TCOM, as have South Korea and Nigeria, for a tethered-balloon Aerosat communications relay station. The Iranian facilities will provide two color television and two FM stereo channels to the southeastern and southwestern areas of the country.\*

#### Brazil

Brazil, as discussed earlier, is now evaluating proposals for a domestic satellite system. The system would employ two satellites and a \$60 million ground system for telephone, television, telex and educational TV. It has been estimated that 2,500 earth stations would be needed and about 20 percent of this purchase is expected to be made in the United States. The competition at present is among a number of U.S. and European groups.

Currently, however, Brazil will use an INTELSAT link as an interim step, until Brazil's requirement can be established. In the meantime, the French and German governments are supporting the European proposal preparations against U.S. competition.

#### Japan

Japan is establishing a domestic satellite communication system, through experiment programs and evaluations. Japan has a launching site at Tanegashima, and has a program underway to develop a full launch capability, including geosynchronous orbits for communications satellites. Their current experimental program requires an annual expenditure of \$100 million.

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\* Aviation Week and Space Technology, February 24, 1975.

In Japan about 97 percent of the population can watch television programs by means of 2,100 NHK transmitters and 1,800 commercial transmitters in combination with community antennas and cable links. The remaining 3 percent of the population in the outer islands is not well served. Research is underway in Japan to improve future color television by increasing the number of lines to 1,000 to 2,000 and improve definition. They are also investigating the broadcast of still pictures and TV text.

There are plans in Japan to launch a broadcasting satellite (JBS) for experimental purposes in 1978, using the 12 GHz band. GE and Tokyo Shibaura Electric Company received \$40 million from the Japanese Space Agency for the JBS, \$30 million going to GE. With this experimental satellite, the following subjects will be studied by the Japanese administration, in cooperation with NHK (Nippon Hoso Kyokai) Japan Broadcasting Company:

1. Experiments for establishing technical criteria for satellite broadcasting
2. Technical experiments on system operation and control
3. Experiments on confirmation of reception effectiveness of satellite broadcasting signals.

The main characteristics of transponders for the broadcasting satellite are shown in Table 3.6.

The Experimental Communications Satellite (ECS) will operate at 4/6 GHz and will be used for operating frequency evaluation. The Japanese Communication Satellite was awarded by JNSDA to Mitsubishi Electric Company (\$10 million) and Aeronutronics/Ford (\$20 million). Antennas and transponder performance for the ECS is shown in Table 3.7.

Table 3.6 Main Characteristic of Broadcasting Satellite Transponder\*

Characteristics	Parameters
Frequency Band	Uplink 14 GHz band, downlink 12 GHz band
Number of TV channels	2 channels (FM)
Antenna	Shaped beam parabolic antenna
Receiver total noise figure	Not more than 8.5 dB
Input and output VSWR	Not more than 1.2
Frequency stability	Not larger than $\pm 5 \times 10^{-6}$ /day
Total gain	Not less than 110 dB
Transmitter output	Not less than 100 W/ch
Output stability	Not larger than $\pm 1$ dB/day
Frequency response in band	Not larger than $\pm 1.0$ dB

\* World Telecommunication Forum, Geneva, 6-8 October 1975, Symposium.

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Table 3.7 Antennas and Transponder Performance for ECS

- Transponder Performance Summary

<u>Parameter</u>	<u>K-Band</u>	<u>C-Band</u>
● Frequency of Operation (nom)	30/20 GHz	6/4 GHz
● Number of Channels	6	2
● Channel Bandwidth (3 dB)	200 MHz	200 MHz
● Output Power/Channel	34 dBm	34.5 dBm
● Input Noise Figure	13 dB	9 dB
● Beacon Output Power	30 mW	25 mW

- All Channels meet 100 Mbps Transmission Requirement

- Antennas Performance Summary

<u>Parameter</u>	<u>K-Band</u>	<u>C-Band</u>
● Frequency of Operation (nom)	30/20 GHz	6/4 GHz
● Coverage Area	Main Part of Japan	All of Japan Territory
● Min Gain over the Area	33 dB	25 dB
● Polarization	Circular	Circular
● Beam Pointing Accuracy ( $3\sigma$ )	$< \pm 0.3^\circ$	$< \pm 0.3^\circ$
● Mission Life	$\geq 3$ years	
● Stationkeeping	Latitude $\leq \pm 0.1^\circ$ Longitude $\leq \pm 0.1^\circ$	

The following types of earth receivers are being investigated by the Japanese:

- Receivers for transportable station (reception only)
- Receivers for stations (reception only) used in terrestrial translator station
- Receivers for stations (reception only) for remote islands or cable TV systems
- Low-noise, low-cost receivers for community/individual reception

The Nippon Electronic Company, Ltd., Tokyo, has been active in satellite communications from the beginning. In 1963 they constructed the Ibaraki station of the Kokusai Denshin Denwa Company, Ltd. and have been very active since in TELESAT construction (see Figure 3.6).

NEC cites as examples of technologies in which they have been very active in ground stations as the parametric amplifier operating at room temperature, the wheel and track antenna, aircooled high power amplifiers, and transportable earth stations with capacity of 60 telephone circuits and one TV channel with INTELSAT IV, giving NEC a strong basis for competing in small earth stations. NEC has also supplied dual polarization antennas and has developed equipment for 11/14 GHz and 20/30 GHz usage.

#### India

India is currently involved in a substantial satellite telecommunications experiment using ATS-6, the Satellite Instructional Television Experiment, where programs from a ground station in Ahmedabad are relayed to 2,000 villages which have community low-cost terminals. The program applications include agricultural techniques, family planning and hygiene, school instruction and cultural integration.

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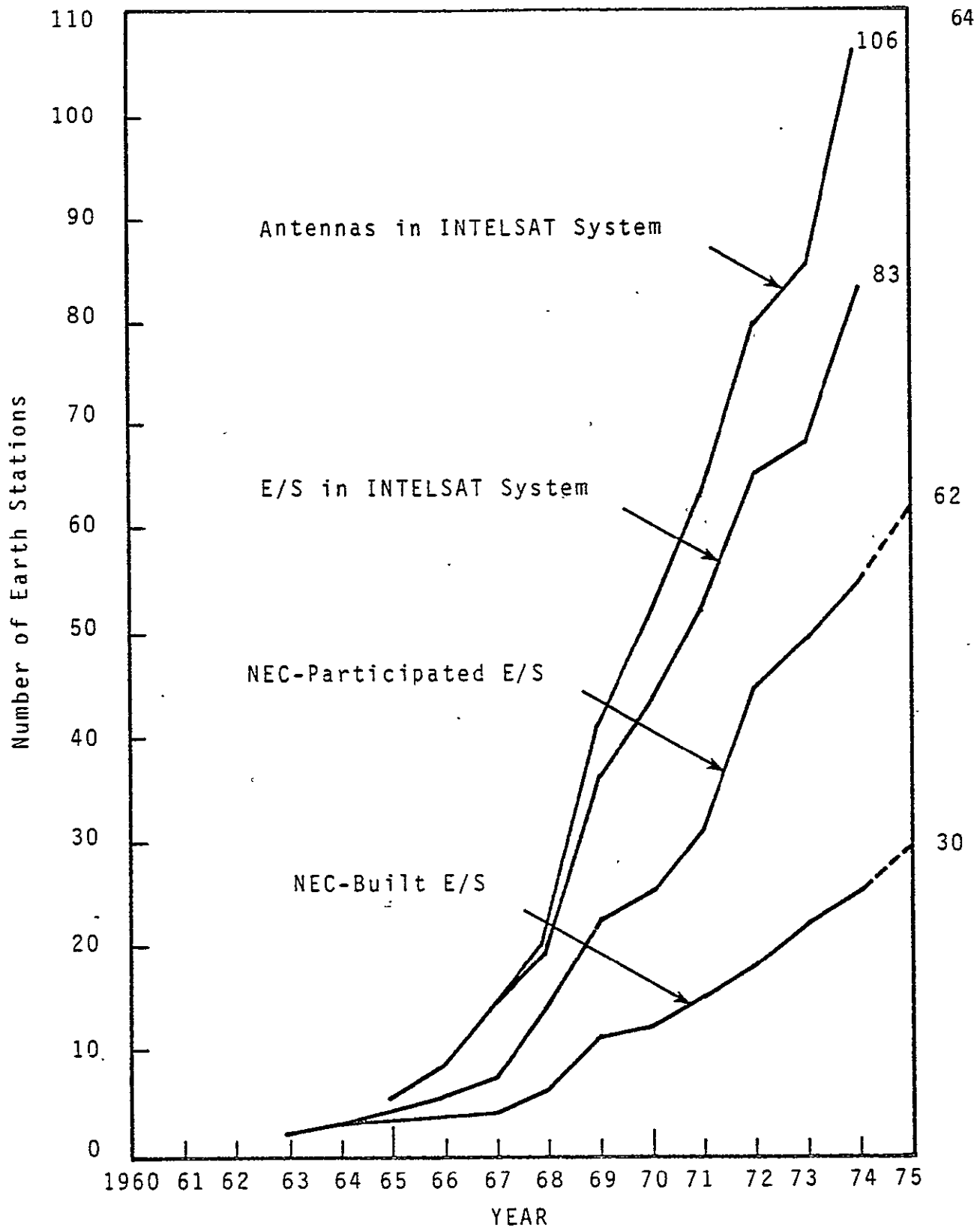


Figure 3.6 Growth of NEC's Earth Stations\*

\*The Manufacturer Looks at the Next Ten Years, Koji Kobayashi, Nippon Electric Company, Ltd.

This nation is seeking to develop satellites for educational broadcasting and their own launch capability (India has a licensing agreement with SEP of France) with the Viking rocket motor.

#### Australia

Australia, through the Australian Post Office (APO), has extensively studied the distribution via satellite of telephone, telegraph, television and educational services. Hughes Aircraft Company was a consultant to the APO to define operational forms, benefits and the economic feasibility of such a system, but as yet APO has made no commitment. Australia, with an area of almost 3 million square miles, an estimated population of about 12 million inhabitants fairly uniformly spread, and a rural population that is reasonably affluent, uniquely seems to be a natural large market for direct-to-home broadcast TV.

#### Countries with No Present Plans for Domestic Satellite Systems

There are no plans in France, Germany or the United Kingdom to develop a national internal satellite communication system. France has planned a system called SOCRATE to provide educational television by direct broadcasting and rebroadcasting to many African French-speaking nations.

Argentina, after study, has decided against a domestic system. The Dominican Republic, New Zealand and the Peoples Republic of China also have no immediate plans to either lease from INTELSAT or to purchase an independent satellite, although the latter has held a number of information exchange meetings with satellite manufacturers, including Hughes and RCA Corp.

### 3.3 Conclusions Concerning Near-Term Systems Applications and Requirements

The obvious conclusion of this survey of current space communications systems and technologies is that an ample base of demonstrated systems and

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technology exists at present to satisfy near-term demands for improved space communications. In the free world the United States space communications industry has been the leader in this field; however, Canada, ESA and Japan have made substantial investments in new systems and technology in recent years. If their investments in new technology, and more importantly demonstration systems, continues, any of these three could challenge the present leadership role of United States industry in the future. It is also apparent that the U.S.S.R. is developing a competitive technology base. The question of whether the U.S.S.R. will use this technology base to compete for systems outside of their present controlled economy client nations remains unanswered at the present time.

A trend toward the development of more complex, higher powered spacecraft that enable the use of less sophisticated, low-cost earth terminals is also apparent. It is of interest to note that it is in this area that United States technical leadership has been challenged, particularly by Canada and Japan.

#### 4. ECONOMIC ISSUES

##### 4.1 The U.S. Space Communications Industry and International Market

The United States is a major producer and user of satellite communications systems, and a major producer of communication subsystems of various terrestrial forms. Funding from the United States government has pioneered communication technology and techniques in space, giving vital support to this industry during its early phases of development. U.S. commercial enterprise has exploited this technology to provide domestic and international communications service delivery by satellite, and U.S. industry has contributed to the progress of technology and techniques.

The U.S. economy has benefited from satellite communications by the use and sale of technology, by the creation of domestic and international systems and from reimbursable launches, tracking and control performed by NASA.

Throughout the world, telecommunications in general has a high national priority, and it promises to develop into one of the largest sectors of the global economy.

Full-scale development of worldwide communications will require the solution of many political, social and financial problems. Even so, it is clear that U.S. technology and products have the potential to capture a significant portion of this market. However, the United States will also be a target market for other national producers of telecommunication equipment.

It is evident that considerable space communications development and hardware activity is in progress throughout the world; and there is a strong upsurge of competition coming from Canada, European Space Agency, Japan and the U.S.S.R. The foreign regional or national demand for space communications

is somewhat uncertain, due to the difficulty in establishing requirements and financing in relation to the economic development needs and capabilities of the nations concerned. It can be argued that communications are indispensable to economic growth, particularly as an enhancement to economic productivity. While this appears to be indisputable, each nation must progress in the development of communication systems at a rate consistent with its own economic power, and each must evaluate its demand for communications, particularly long distance communication. Thus, in the near term, many nations could experiment with the use of space-based systems to meet the requirements by leasing transponder(s) from INTELSAT or other available systems, without a large national capital investment.

The United Nations recognizes some 153 industrial and developing countries, yet of these nations only 42 have more than 0.5 million telephones and only 21 have more than 15 telephones for each 100 people. In comparison, the United States has about 144 million telephones (about 39 million business telephones) or approximately 68 for each 100 people.\*

It seems clear that the developing nations could be a primary foreign market for the U.S. space industry. For these nations economic development could require a directed allocation of capital among a variety of public services to assure a growth pattern that is consistent with its planned future. A properly selected communication service may be an appropriate economic means to provide improved health services, education, agricultural assistance,

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\*The World Telephones, ATT, 1974.

and other public services.\* There is a possibility that developing nations could bypass the traditional processes of national development, by the use of space communications and as a result conserve capital and reduce energy consumption.. At this time the economic trade-offs between appropriate communications (including space systems) and alternative means of distributing public services remains unclear, as does the definition of the most desirable communication service delivery mix. In fact, the impact of improved communications on the productivity of public services is in itself not determined at the present time. However, the objective of any government should be to enhance overall communications capability in response to the needs of the largest segments of the national population. Thus, a bias of government support toward the satellite communications industry for special applications would appear to be unsound if the more general telecommunications industry would suffer as a consequence.

Uncertainty exists in the technical requirements of the necessary communication needs of the developing countries. The mechanisms and conditions attached to obtaining the capital necessary for creating their communications facilities are also uncertain. An additional factor is the relative newness and lack of long-term stability in many of the Third World governments. Plans as well as programs being implemented are subject to revision or cancellations, as priorities are perceived by changing political forces, especially for high-cost, long-term programs such as space communications. The developing nations require time and assistance to:

- Formulate national communication policies and needs
- Structure national institutions

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\* Examples of such applications are found in Alaska's Health Care Satellite, HEW's Telehealth program, India's educational broadcasting.

- Provide the necessary supporting technology for applications
- Find the capital required to finance the development and operation of these systems.

In addition, the developing nations are becoming increasingly concerned about the economic utilization and conservation of energy. Effective internal and external communications could contribute to these objectives. Such communications needs can be responded to most appropriately if communications alternatives are fully understood technologically and economically. (ESA, in its planning, recognizes the necessity to integrate technology, experiments, industrial suppliers and financial organizations in its attempt to achieve optimal competition.)

It would also seem reasonable to assume that an extensive and diversified economy such as that of the United States has more need for an extensive, diversified and flexible communications system (which, in fact, exists today) than the majority of the world's nations. Yet the development and application of innovative space communication concepts proceeds very slowly in the United States with time lags that often extend ten to twelve years from concept to operational systems. Such delays are caused by many factors--some technical, others political, economic, institutional and regulatory.

The so-called "Electronic Mail" via satellite serves as one example of a possible new service opportunity which involves several of these factors. To effectively implement such a service would require a number of new technology developments, but there are formidable institutional and possibly regulatory barriers (especially in the United States) which must also be overcome. Even the economic issue is somewhat obscured by the fact that although major cost advantages are fairly easy to predict in the operations of an electronic delivery system over conventional delivery systems, there would also

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be significant accompanying tariff losses by present handling and delivery systems, as well as direct job losses to many postal employees.

The technology problem is, basically, that: (1) it will be a decade or longer before sufficient insight into systems needs (for technologies) is developed; (2) it is not now known what developments would be most likely to provide the desired performance; and (3) will there be the conviction and backing to carry the program to completion.

Domestically the United States is faced with communications implementation problems similar to those of the rest of the developing world, with a difference because of the scale and extent of previous investment in terrestrial communications systems. While it would appear that the complex U.S. economy would maximally benefit from appropriately defined space communication systems, that same economy could be damaged by injudicious development of its communications mix. Progress is necessarily slow and cautious.

If the United States is to continue to sustain its standard of living, it must seek to revitalize productivity by minimizing economic waste, constraining inflationary trends, expanding its export market shares and finding means to expand social justice without creating false expectations. While space communications systems appear to provide possible solutions to some of these problems, space communication system entrepreneurs must move cautiously because of considerable real and apparent economic risks. Combined with an increasingly complex communication structure are risks and uncertainty in:

- Market estimation
- Technology required
- Technology reliability
- National telecommunication policy
- Future regulatory decisions and the speed of regulatory adaptation
- Costs of marketing.

On the other hand the U.S. government must be aware that communications applications have considerable power to change the national lifestyle. Thus the government needs to be concerned about the resulting economic disruption if changes proceed too rapidly. Further, governmental concern must extend to the potential conflicts that can be generated between the communication requirements of government, industry, and commerce and those portions of its society deprived of full participation in the nation's service resources.

Overall, the economy of the United States has made a transition from a "goods" economy to a "service" economy as technology has tended toward the development of a capital rather than a labor intensive economy. Increasing demand for capital has intensified the shortage of capital, particularly as the developing nations require financing in their struggle toward economic equity. However, developing nations presently utilize technology to create labor intensive activities rather than capital intensive ones.

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To better understand the interdependence of the U.S. telecommunications industry and the world market, a brief explanation of the U.S. industry share of the world telecommunication market and balance of payment is provided in the following section.

#### 4.2 U.S. Economy and Balance of Payments

The U.S. industry share of the world telecommunications market will impact the U.S. economy and international balance of payments. The impact can be described in terms of productivity of capital and labor, inflationary and currency devaluation effects, and profit, each resulting from an export-import interface with other nations. In discussing these economic measures, the relationships between existing telecommunications market shares and U.S. national dependencies involved in maintaining and expanding these potential worldwide market shares will be reviewed.

The balance of payments is derived from an accounting of the flow of goods, services and capital to and from the United States and its trading partners. This accounting procedure identifies two basic accounts, a current account and a capital account. The trade or current account consists of the trade or merchandise and an invisible account which records payments, receipts for services, interests, dividends, profits, royalties, fee transfers and remittances. The capital account records all short- and long-term capital inflows and outflows. The sum of the current and capital accounts yields the balance of payments.

Commodity or trade accounting is concerned with all goods imported and exported by the United States including merchandise stored in bond, i.e., not immediately consumed, and merchandise that is re-exported. Balance of



payments accounting requires that imports be valued free on board (f.o.b.) at a foreign port and that exports be valued free alongside ship (f.a.s.) at the port of export. A great deal of difficulty is frequently experienced in separating out freight and insurance charges, and complication arises in distinguishing between U.S. flag and foreign vessels. Transfers of merchandise between U.S. parent and foreign subsidiary corporations may distort the balance of payments because transactional or transfer prices may not reflect true commodity market values.

Direct investment results from an acquisition of an interest in a foreign enterprise or activity by a U.S. organization. This can be a stock acquisition, financing of inventories or accounts receivable, purchase of existing facilities or the building of plants and equipments. Direct investment in plants and equipments may, by itself, result in an increase in U.S. exports. Direct investment can increase without any dollar flows through retained earnings although this might also reduce dividends or profits returned to the United States.

Goods exported by the United States to other nations are generally paid for in the currency of the receiving nation, which is of value to the U.S. exporter provided that the currency can be converted or, if the conversion is indirect, through counterbalancing exports from that nation to the United States.

Nations are relatively free to establish selective economic barriers to inflows of commodities and capital, of any type which will result in revenue for them or which will result in their own direct economic development.

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Balance of payments accounting procedures or those for balance of trade are rather complicated and involuted, in the sense that the precise influence of a selective trade increase in a given sector cannot necessarily foreshadow an improvement in the national balance of payments or the national balance of trade over time. That is a fact that must be demonstrated by examination of the economy as a whole.

The issue here is the significance of increasing the balance of payments in one industrial sector of the economy, the sector dealing with telecommunications. A significant increase in the balance of trade in this sector will not assure an improvement in the national balance of trade because of the interdependence among the many other sectors of the national economy. The following section outlines the telecommunications market trends for U.S. exports.

#### 4.3 Market Trends

The United States' share of world exported technological products has decreased since 1954 while the share of other industrialized nations has increased (see Table 4.1).

With an increasing U.S. consumer demand for electronic imports, the U.S. trade balance for electronic and communications equipment (SIC 3651, 3652, 3661, 3662, 367) has declined from a 1965 surplus of \$206 million to a deficit of \$980 million in 1973 (see Table 4.2). This trend had been slightly halted during the 1973-1975 period due to increasing rates of inflation and currency re-evaluation, which have effectively decreased the value of the U.S. dollar. Consequently, the trade deficit in electronics communications in 1975 was about \$525 million.

Table 4.1 Share of World Exports of Technological Products

Country	% Share	
	1954	1970
Japan	1.8	9.7
Italy	2.4	6.0
France	6.4	7.8
West Germany	17.6	21.0
United Kingdom	19.0	10.3
United States	35.3	23.0

United States Commerce Department, cited by M. Boretsky, "U.S. Technology: Trends and Policy Issues," George Washington University, Monograph No. 17, October 1973.

Table 4.2 Communications-Electronic Industries  
United States Production and Trade\*

Year	1967-1973 (millions United States \$)		Balance
	Imports	Exports	
1967	828	953	+125
1968	1164	1113	- 48
1969	1568	1436	-132
1970	1800	1619	-181
1971	2124	1554	-570
1972	2841	1897	-944
1973	3697	2717	-980

\* SIC code 3651, 3652, 3661, 3662, 367

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The 1973 exports of telephone and telegraph equipment increased by 47 percent over the previous year. U.S. imports more than doubled during the same period.\* This created a deficit balance of \$13 million which was attributed to the rising imports of Japanese and Canadian interconnect equipment.

While the trend in the telephone and telegraph associated industries has resulted in negative trade balance for the past several years, the commercial, military, industrial and electronic components sections have maintained favorable balances. It is not the highly technical and specialized products which account for favorable trade balances for the United States. It is, rather, the low technology mass produced components which have accounted for the significant percentages of our communications and electronic exports. The semiconductor industry, for example, represents the largest portion of the various electronic components groupings, accounting for over 50 percent (1973) of the exports and 70 percent of the imports.

The general SITC code for telecommunications trade accounts (SITC 724) is subdivided into categories of specific equipment types. Three basic classifications which would include much of the satellite telecommunications system components would be TV receivers (SITC 724), radio broadcast receivers (SITC 7242) and telecommunications equipment NEC (SITC 7249) (see Table 4.3, Figures 4.1 and 4.2).

In summary, it has been the rather low technology mass-produced telecommunication products which have been responsible for most U.S. telecommunications export. Even a significant increase in the total U.S. telecommunications

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\* U.S. Department of Commerce News, July 18, 1974.

Table 4.3 SITC Coding

724	Telecommunications Apparatus, & Parts
724.1	Television Broadcast Receivers
	Television Broadcast Receivers, Color, Whether or Not Combined with Radio or Phonograph
	Television Broadcast Receivers, Except Color, Whether or Not Combined with Radio or Phonograph
	Television Tuners
	Television Chassis, and Unassembled Television Kits
724.2	Radio Broadcast Receivers
	Radios, Household Type, Without Phonograph
	Radio-Phonograph Combinations, Household Type
	Automobile Radios, Other Than Two Way Radios
	Radio Tuners, Radio Chassis, and Kits for Assembly
724.9	Telecommunications Equipment, NEC
	Telephone Switchboards
	Telephone Switching Devices
	Telephone Carrier Equipment, & Parts NEC
	Teleprinter Units, Wire
	Telegraph, Wire Apparatus and Equipment, NEC
	Teleprinter Units, Wire
	Telegraph, Wire Apparatus and Equipment, NEC
	Loudspeakers, and Parts, NEC
	Microphones, and Parts, NEC
	Amplifiers, Audio-Frequency, & Parts NEC
	Public Address Systems, Consisting of Speakers or Horns, Amplifiers, and Microphones
	Telephone Repeater Equipment
724.9905	Transmitters and Radio Frequency Power Amplifiers, Except Broadcast type
	Transceivers, Single Sideband High Frequency
	Radio Communication Systems, Except Mobile and Microwave
	Microwave Communication Systems and Equipment
	Mobile Communication Equipment, NEC
	Communication Equipment NEC, and Parts, NEC
	Transmitters, Radio Broadcast
	Transmitters, Television Broadcast
	Radio and Television Broadcast Audio Equipment
	Television Broadcast Studio Equipment, Except Video Tape Recorders
	Closed Circuit Television Systems and Equipment, NEC
	Parts & Accessories, NEC, for Tuners & Chassis, Radio & TV Receivers
	Parts & Accessories, NEC, for Radio & TV Broadcast Equipment, NEC

Table 4.3 SITC Coding (continued)

724.9905 (cont.)	Inter-Communications Equipment, Except Wire Telephone and Telegraph Electronic Navigational Aids Electronic Search and Detection Apparatus, Including Radar Electronic Telecommunications Equipment, NEC Parts and Accessories, NEC, for Telecommunications Equipment
726	Electronic Equipment capacitors solar cells electrical furnaces silicon rectifiers silicon diodes semiconductor diodes transistors condensors electric discharge lamps cathode ray tubes TV camera tubes storage and primary batteries hot cathod mercury vapor lamps arc welders oscilliscopes solid state semiconductor devices

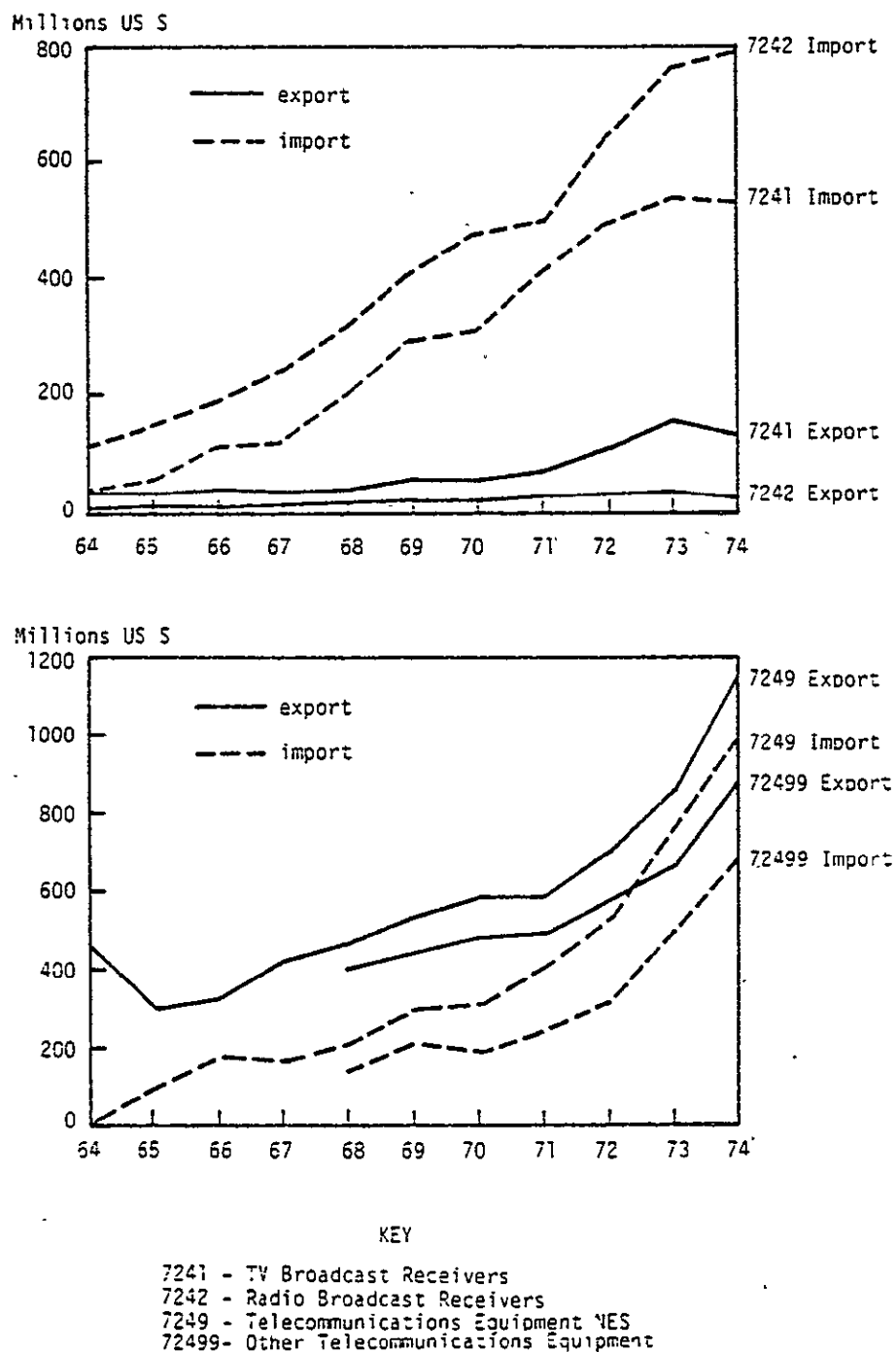


Figure 4.1 Import-Export for Various Industrial Sectors by SITC Codes

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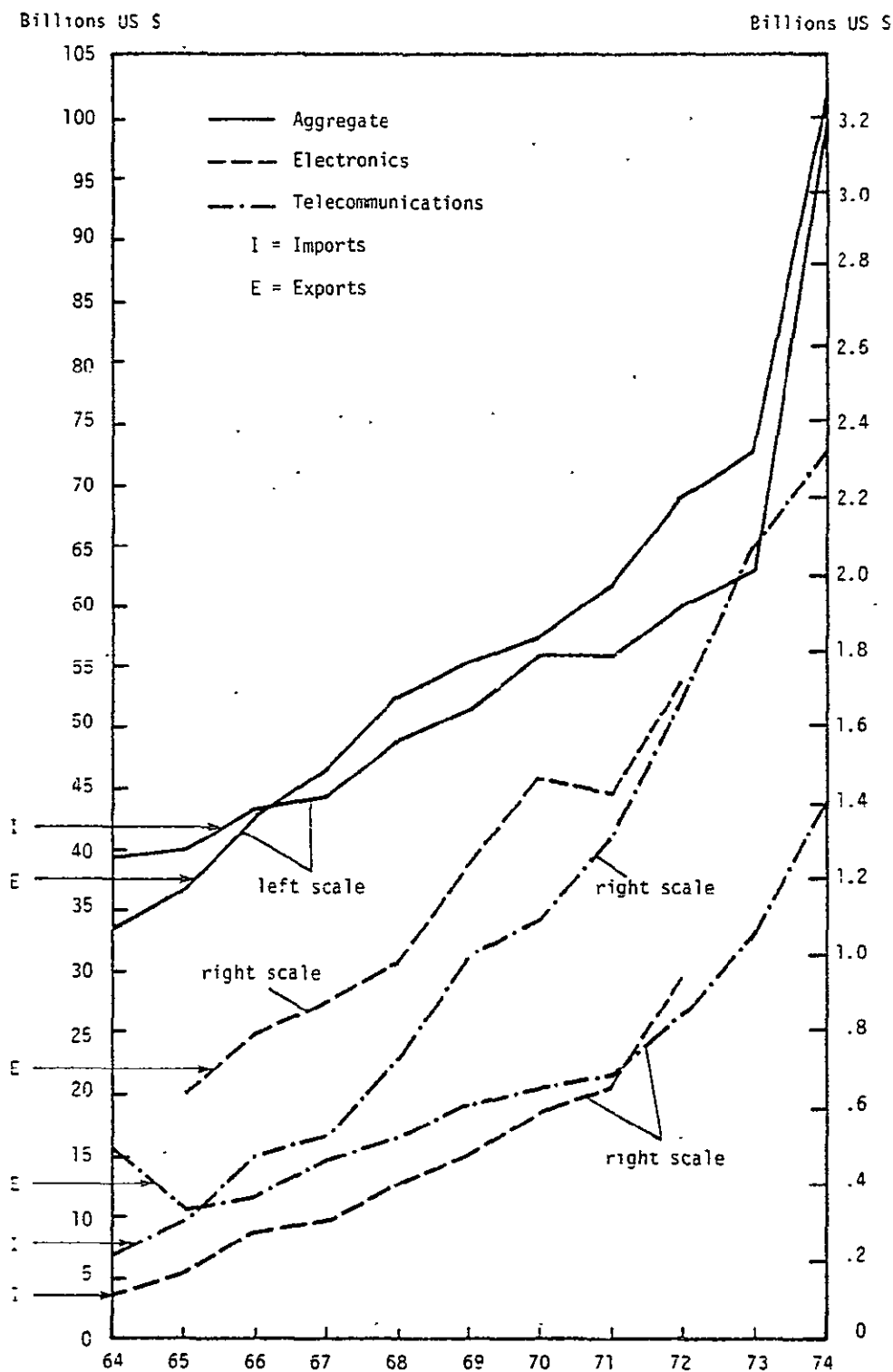


Figure 4.2 Total United States Import and Export for Aggregate, Telecommunications and Electronics Industrial Sectors, 1964-1974



export, which is presently less than 4 percent of the nation's aggregate, would be insignificant toward any improvement in the national balance of trade.

#### 4.4 Relationship of Government Supported Research and Development to the Economy

By not investing in high risk technological R&D, government can substantially constrain the rate of introduction of new technology into the economy and to a degree control the rate of increasing demand for capital. National and international market demands for new technologies would then be dependent upon private enterprise or foreign sources. However, this introduces risks in the availability of technology and makes it impossible to formulate a national policy and regulatory framework consistent with the capabilities of communication technology. Clearly, if it is the policy of U.S. government to slow the progress of the domestic market, other nations in the market for technology-based systems will turn to non-United States sources.

A well-formulated, successful R&D program with adequate and timely funding for the maintenance of its momentum and continuity can bring into being technology which will minimize the time from concept to operational implementation. Yet underlying the decision to fund R&D for the globally significant space communication systems are many substantive economic issues which may or may not favor a positive R&D funding decision. These tend to be most concerned with the timing of the necessity for the technology.

Federal funding has pioneered space communications. Federal action has motivated the implementation of commercial international satellite communications and has facilitated commercial domestic satellite communications.

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At the present, foreign innovative developments in space communication are still (to a great extent) dependent on United States design knowledge and fabrication technology. A multiplicity of United States civilian domestic applications are also underway in telephone switched traffic, private line telephone traffic, record traffic, public television distribution and pure data traffic. Also under development are systems for control of aircraft and ships and terrestrial mobile systems in which communications is used for improved operating management efficiency. In addition, federal funding of military space systems and research has also continued.

At this time the principal remaining investigations relate to the operation of a satellite as a multiple node network. This requires experiments that will determine the maximum power density regulated bandwidth product with noninterfering sidelobes, as a function of regulated frequency. The number of such separate point functions that can be generated or the number of switched beams that can be accommodated and controlled must be investigated. Associated with this is the development of the matched earth segments. Shaped beam technology will be necessary.

The R&D, if performed and if successful, would supply knowledge of a feasible technological capability. From this experimental basis a variety of application structures could be developed, with reasonable confidence in effective operation, once implemented. It is from these application structures that economic and social benefits from the R&D will emerge, consisting of five basic components:

1. Continuing employment in the space communication industry
2. Better competitive position in the world market
3. Improved national productivity

4. Improved international productivity

5. More effective overall spectral and orbit efficiency.

Component (1) assumes that some federal R&D funds will be spent in the space communications industry, maintaining a work force engaged in R&D and applications development. Component (2) assumes that the availability of the successful results of the R&D will generate production for the industry. Component (3) assumes that there is a diverse set of national applications dependent on the R&D results which relate to national government, industry, commerce and social services. These are either new forms or incremental improvements to old forms, reducing service prices, improving the total national export posture and allowing U.S. governmental policy and regulation to proceed effectively. Component (4) is concerned with the incremental gains to the United States from exports to nations or regions whose internal economic productivity benefits from the space communications supplied. Component (5) visualizes benefits that arise from a more precise understanding of international need and the relation that need has to the United States, so that both the spectrum and orbit can be allocated and used to maximum U.S. benefit.

The above total benefits from the R&D funding can only be realized if the effort results in a demand for specific services.

#### 4.5 Conclusions Concerning Economic Issues

The U.S. balance of trade for communications and electronic equipment has been negative for every year since 1968. In 1973, the most recent year in which complete data was available, telecommunications and electronic equipment exports accounted for less than 4 percent of the aggregate U.S. exports. In view of the relatively small size of this sector (both import

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and export) it is probably not valid to argue that the expenditure of federal research and development funds could significantly affect the U.S. balance of trade at some future date.

It is an observable fact that an adequate communications system is an inherent part of an industrialized economy, and that in the case of developing economies, improved domestic and international communications are necessary for economic growth. Although most readers will accept this conclusion as axiomatic, the relationship between communications and economic productivity has not been quantified. Until a better understanding of this relationship is obtained it will be difficult to accurately estimate the economic benefits of improved communications. This lack of understanding of the economic effects of improved communications may be a contributing factor to the inhibition of the growth of advanced communications systems in both the developing and industrialized nations.

## 5. LONG-TERM FUTURE APPLICATIONS AND REQUIREMENTS OF COMMUNICATIONS SATELLITE SYSTEMS

In the near term it appears that existing technologies are probably adequate to satisfy those worldwide communications requirements that can be defined. When a number of emerging nations reach the stage of full understanding of and planning for their total systems needs--which frequently will include large numbers of low-cost earth stations--then technologies must be available which will satisfy those needs at costs which are acceptable or favorable compared with alternatives. This same need holds for advanced nations when the time comes to implement more sophisticated systems to perform new services, or older ones more cheaply.

Obviously, space communications can be further expanded through research and development. Areas where advances seem most likely include higher radiated power, new transmission frequencies beyond the current range, new modulation and bandwidth expansion methods, beamshaping, multibeam, on-board processing and switching, and wide-band data transmissions using time division techniques. Many of these techniques lead to the possibility of small, low-cost ground stations, including small, mobile earth stations.

### 5.1 Trends in Space Communication Activities

In existing systems, the space segment of a satellite communications system acts as a repeater for transmitted signals from ground stations.

These satellites typically consist of two distinguishable major components: the bus and the communications payload. The bus provides all support

functions for the payload. These include structure, power, thermal control, stabilization, propulsion, and telemetry and command. The communications payload represents the transponders and associated antennas and other electronics. Factors which influence the final satellite design include mission requirements, launch vehicle constraints, and the state of technology. Trends in technology development associated with the spacecraft are discussed in this section. Three distinct areas separate the discussion in terms of technology trends: general satellite configurations, spacecraft bus and communications technologies.

#### 5.1.1 General Satellite Configurations

The configuration of a satellite is derived from a compromise of mission requirements, launch constraints, orbit selection, power source, and stabilization technique. In recent years each satellite contractor seems to repeat a basic configuration for several programs. The classic example is the dual-spinner line of Hughes Aircraft Co. This line includes INTELSAT IV, INTELSAT IV-A, WESTAR, ANIK, the Indonesian Satellite, and COMSTAR I. The program funding level is also an important factor in determining a satellite configuration. Evolution to new configurations is a slow process, and it appears that only two contenders are viable for the 1980s. These are generally classified as dual-spinners and 3-axis (or body) stabilized designs. The former configuration has the longest record of success, but the recent communications satellite trend is toward 3-axis designs. The first operational satellite of this type is the RCA Satcom, launched in December 1975 and again in March 1976. INTELSAT V, to be built by Aeronutronic Ford, is also a 3-axis design. A recent innovation by Hughes Aircraft Co. is the proposed shuttle-optimized spacecraft for the orbital flight test program

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(OFT). This cylindrical dual-spinner would utilize the full 15-foot (4.6-meter) diameter of the shuttle bay and would be 10 feet (3 meters) long in its stored configuration. This spacecraft would have sufficient body solar cell area to generate 2 to 3 KW of power, according to Hughes. This would make it a potentially viable alternative to 3-axis designs, especially if solar cells continue to decrease in cost.

Most communications satellites have been launched into synchronous altitude orbits. This permits the stationing of a spacecraft over a constant position with respect to the earth's surface. In principle, this leads to stationary, simple ground antennas. However, a disadvantage to this selection is that coverage is restricted to nonpolar regions of the earth, and the high circular orbit requires a comparatively large total velocity increment from the launch vehicle system and its integral kick stage. Also, there exists a variety of perturbing forces which tend to pull geostationary vehicles off station, including lunar-solar attraction which requires about 50 meters per second per year of velocity increment to counteract it.

The geostationary orbit is not completely suitable for coverage at high latitudes. The U.S.S.R. solution was the highly elliptic, high inclination Molniya satellite. However, most nations are located at latitudes low enough to use equatorial satellites quite adequately. Thus, the expanded use of geostationary orbits is inevitable. Figure 5.1 shows the satellites placed into this region prior to 1970. Figure 5.2 illustrates only those injected in a five-year period ending on December 31, 1975. Satellites of undisclosed configurations are shown as question marks. Finally, Figure 5.3 presents the currently projected launches after January 1, 1976. Clearly, the desirable

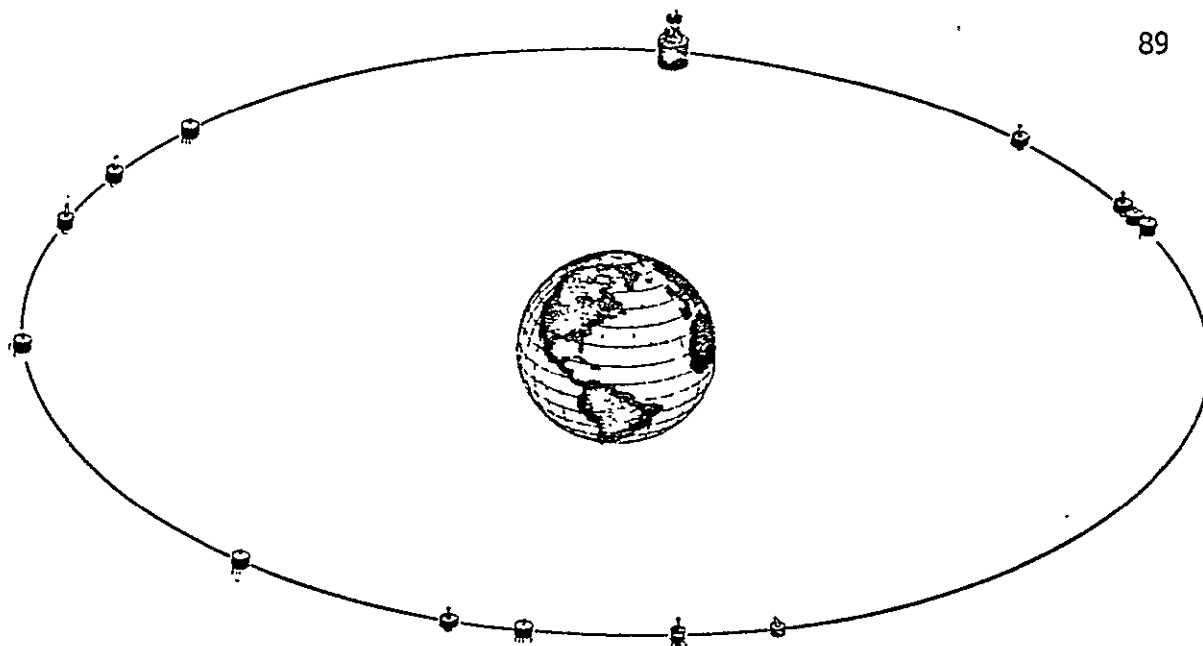


Figure 5.1 Geosynchronous Satellites Launched Prior to 1970 (Source: COMSAT Technical Review, Spring 1976)

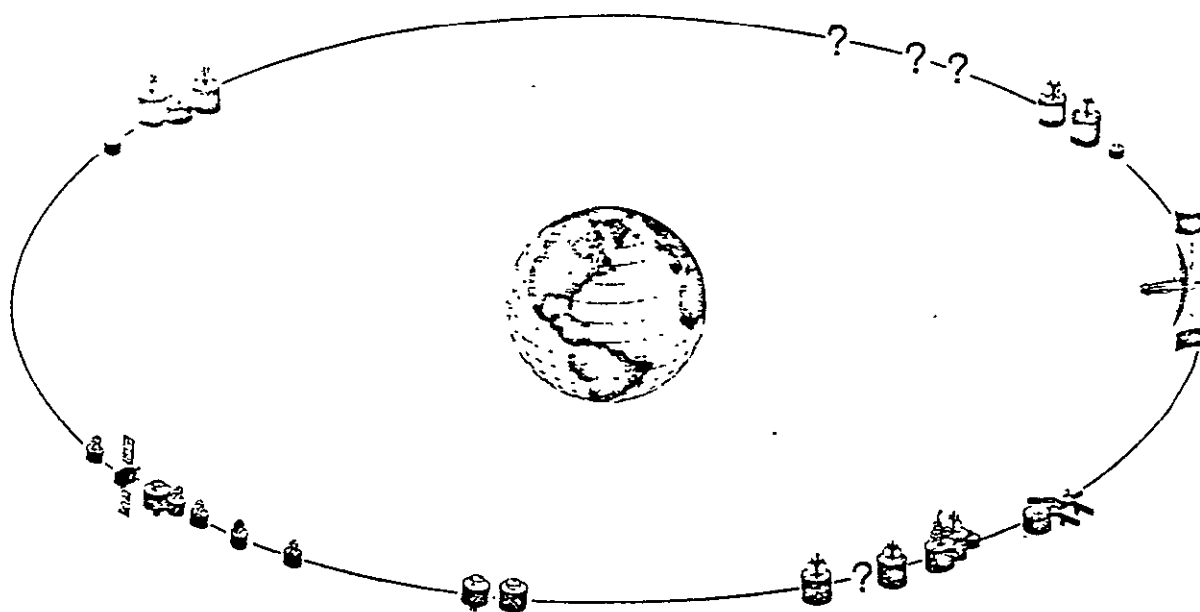


Figure 5.2 Geosynchronous Satellites Launched Between 1970 and December 31, 1975 (Source: COMSAT Technical Review, Spring 1976)

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equatorial orbital spaces are becoming a premium commodity. Considerable care and planning is vital to insure each slot provides maximum benefits in an equitable manner.

Stabilization of communications satellites can be classified according to the relative amount of inherent momentum. Spin-stabilized satellites possess a great deal of angular momentum, are gyroscopically very stiff, and have relatively simple control systems. Bias momentum configurations are

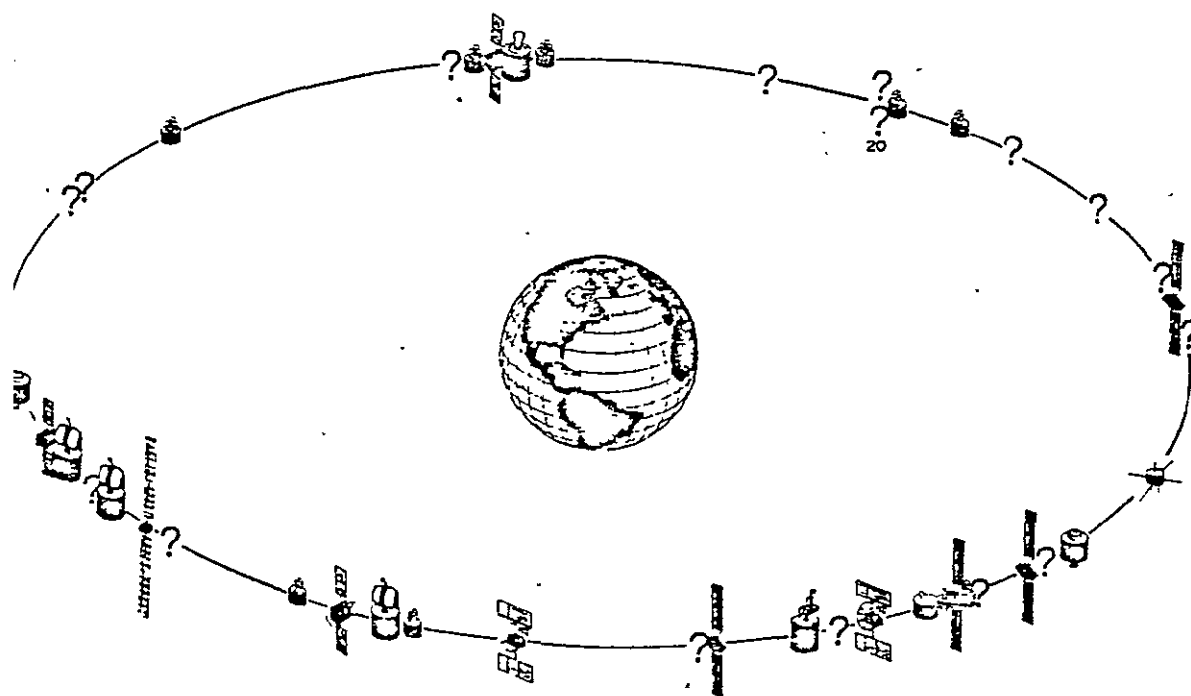


Figure 5.3

Geosynchronous Satellites Launched or to be  
Launched After January 1, 1976 (Source: COMSAT  
Technical Review, Spring 1976)

characterized as incorporating a momentum wheel which is maintained at a nominal level of angular momentum. Such satellites are, in fact, 3-axis stabilized with a large platform to carry the communications payload. Finally, there are zero-momentum systems which use reaction wheels, whose nominal momentum is zero.

In designing satellite subsystems and integrating them into a complex spacecraft the philosophy has been to minimize cost while using proven components. One-of-a-kind production techniques have led to early obsolescence and a large variety of satellite configurations. This is attributed to a high rate of technology increase and "one-way" launch techniques. Thus, once a satellite is placed in orbit there is presently no way to retrieve or repair it. Furthermore, rapidly changing requirements and technology essentially guarantee that satellites in orbit are obsolete for repair or use beyond their specified lifetimes. However, history has proven that increases in development of new technology in a specified field tend to level off after an initial surge of activity. Communications satellite innovations may be approaching this situation. Thus, spacecraft will become obsolete less rapidly and will be designed for longer life as well as repairability. The introduction of the Space Shuttle in 1980 and the reusable orbit-to-orbit tug in the mid-1980s will provide a means for retrieval and repair of satellites which should provide an incentive for the introduction of modular configurations which are serviceable on orbit. It has been estimated that body-stabilized communications satellites can be designed to be repairable with a 25 percent

increase in mass and an 8 percent increase in production costs.\* Spinners would be markedly more difficult to service. Potential benefits from servicing or repairing in orbit include: increased reliability, decreased life cycle costs, installation of updated equipment, a much improved basis for failure analysis and correction of design weaknesses. It is possible that the use of servicing techniques could result in overall cost savings of 40 percent or more when compared with replacement methods used today. Figure 5.4 presents sketches of a serviceable satellite concept. Modules with high heat dissipation, such as those with transponders, can radiate directly to space from the north and south panels. Other faces can be insulated. Propulsion modules are located in the four corners for maximum torquing effectiveness. Each of these modules contains a hydrazine tank, valves, filters and a thruster assembly with five thrusters. Therefore, no fuel lines need be cut when replacing modules. Figure 5.5 illustrates one potential configuration of an orbit-to-orbit tug as it approaches a modular communications satellite. Although such tugs will not be operational until the latter 1980s, they could have a significant impact on satellite design much earlier.

The Shuttle orbital altitude is severely limited, requiring that synchronous payloads use both an upper stage or perigee kick motor to achieve transfer orbit and an apogee kick stage. Although ESA and Japan are developing conventional boosters of the Atlas/Centaur and Delta classes, respectively, expected costs will probably exceed that of the Shuttle, especially with the

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\* Kaplan, M. H., "Active Attitude and Orbit Control of Body-Oriented Geostationary Communications Satellites," AIAA in Astronautics and Aeronautics: Communications Satellite Technology, Vol. 3, 1974, pp. 29-56.

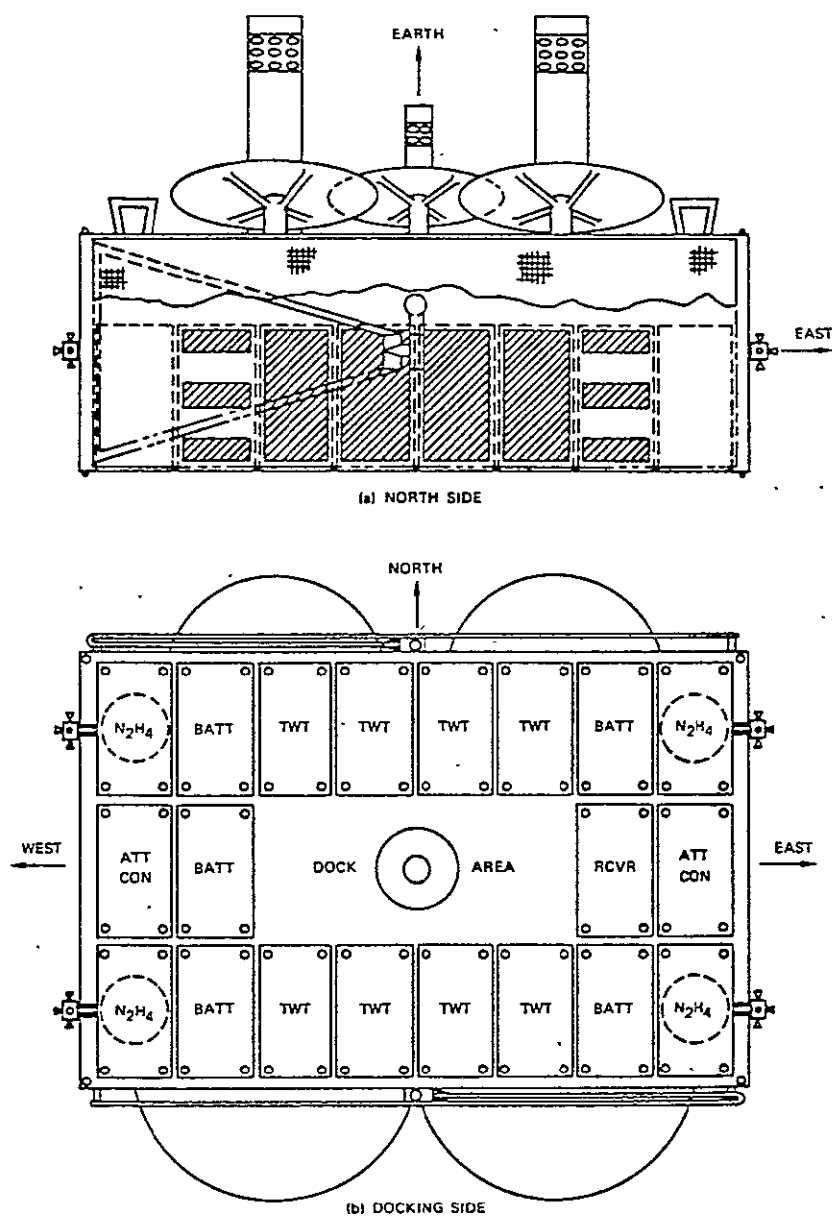


Figure 5.4 Serviceable Communications Satellite Configuration

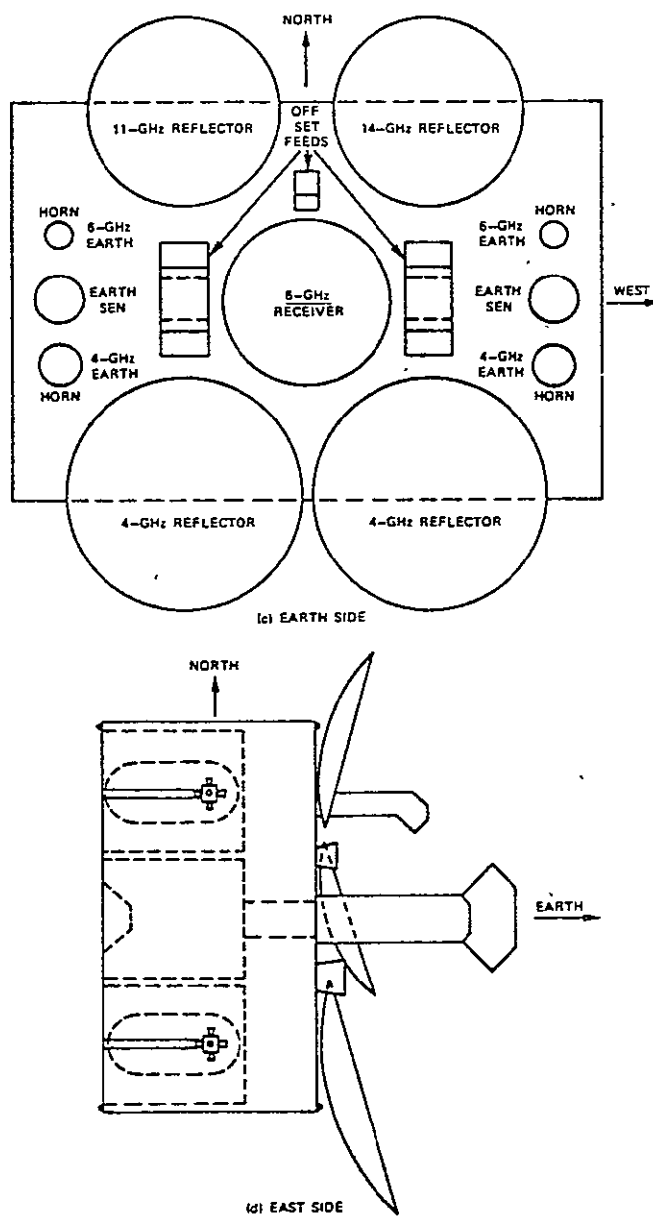


Figure 5.4 Serviceable Communications  
Satellite Configuration (Continued)

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possibility of using the Shuttle for multiple launches. Shuttle launches should reduce transportation costs to low orbit by a factor of 2 or 3.

Launch restraints and environment are greatly relaxed with the Shuttle. Figure 5.6 depicts the payload bay and attachment points.

Figure 5.7 illustrates the expected acceleration environment in the payload bay during launch and re-entry. This represents a significant reduction in dynamic loads. However, there is a crash load requirement of up to 9 g associated with an emergency return and landing.

To summarize the trends in communications satellite configurations the key items are listed below.

1. Introduction of the space shuttle will have a major impact on satellite design. Larger and more massive vehicles will be permitted. However, their complexity need not increase, because the Shuttle can provide initial checkout and

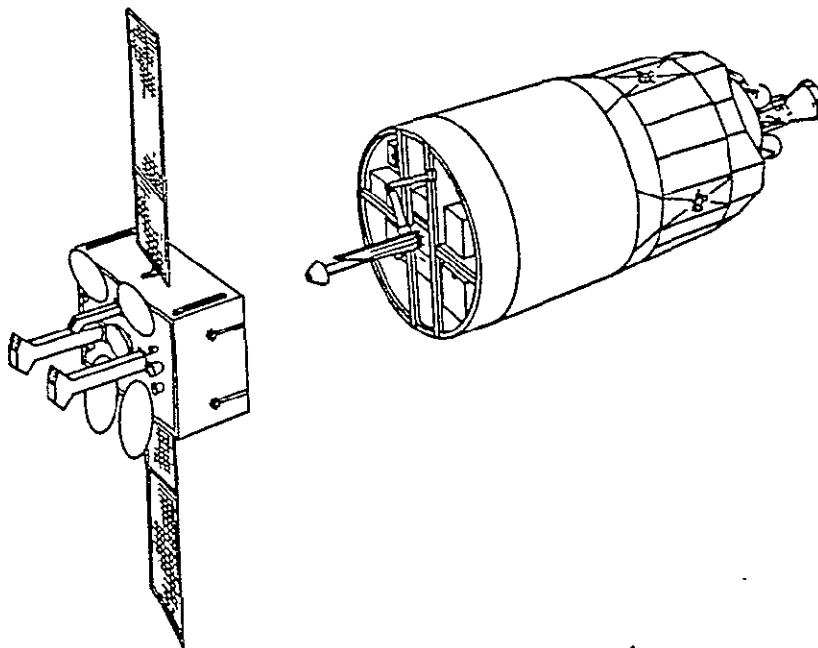


Figure 5.5 Full-Capability Tug on Servicing Mission

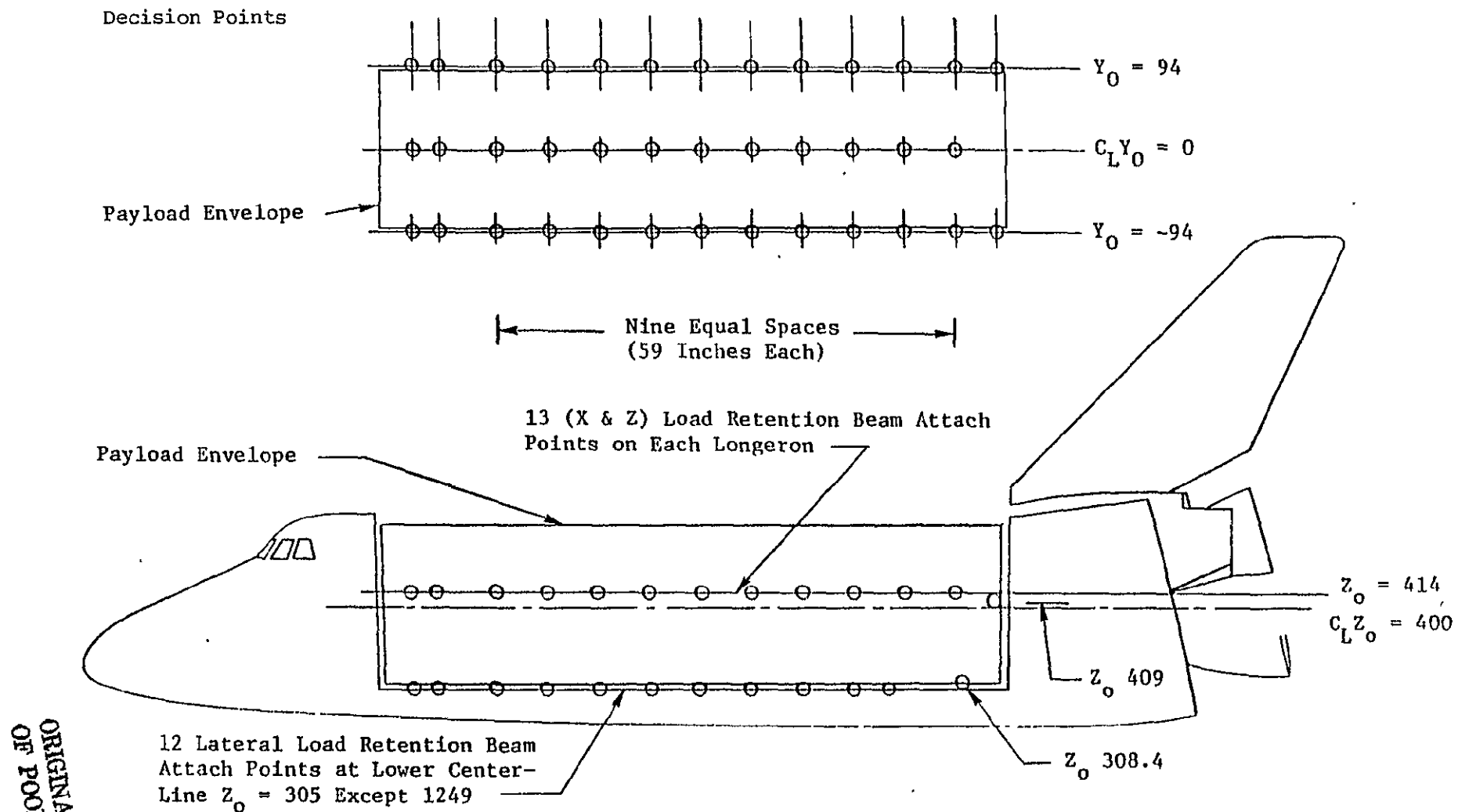


Figure 5.6 Shuttle Payload Bay and Attachment Points

deployment conditions. The trend appears to be toward placing a maximum burden on the Shuttle in terms of support equipment and procedures for deploying payloads. Such accessories will be returned to earth and be reusable.

2. Stabilization techniques to be considered for the 1980s include dual-spin, bias-momentum, and zero-momentum systems. The present trend appears to be one of increasing use of body-stabilized configurations.
3. The logical progression of subsystem development is toward modular, serviceable configurations, which is possible with the use of a tug vehicle. Since development of the tug has been delayed until at least the mid-1980s, modular designs cannot be expected before then.

### 5.1.2 Bus Technology

Subsystem technology is rapidly advancing. Almost every major component of the spacecraft bus will benefit by advances in hardware design and new innovations. This section concentrates on reviewing expected developments in major bus subsystems through the 1980s. Considerations include energy sources, structures, attitude control and propulsion. Basic satellite configurations were discussed in the preceding section.

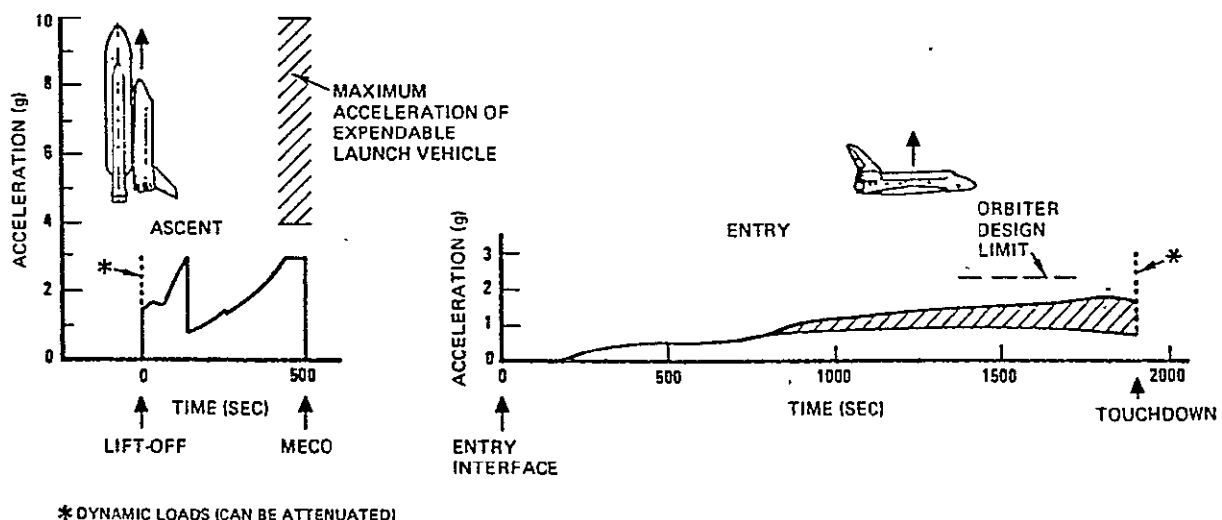


Figure 5.7 Acceleration Environment in Payload Bay



There will be a need for higher power capability in communications satellites in the 1980s and beyond. Typically, one can expect D.C. power requirements to range between 1 and 3 kilowatts for the progressively larger and more complex spacecraft. A number of candidate energy systems for communications satellites have been examined over the years. Photovoltaic conversion of solar energy continues to offer significant advantages in terms of both specific power and specific cost for synchronous orbit at power levels up to a few kilowatts. The present trend is toward improved power density and reduced size, which indicates a continuing preference for solar power. Nuclear power is an alternative using isotopes as the power source for the range of interest. Indications are that nuclear power supplies should not be considered as simply substitutes for solar power supplies. Because nuclear power supplies have a significant impact on overall spacecraft design\* (it appears that they may result in less massive, more reliable, higher cost buses), life-cycle costs of systems utilizing nuclear power may be less than those of systems using solar power.\*\* This requires careful examination and the results will be very dependent upon specific mission requirements, for example, the usefulness of RTGs is more evident in low altitude orbits with high shadow times.

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\* Raab, B., J. J. Karlin, Solar Versus Nuclear Power: Is There a Choice?, AIAA Paper No. 74-489, April 1974.

\*\* Greenberg, J., R. Nichols, Economic Impact of New Technology on Domestic Satellite Communications, AMS Report No. 1285, Princeton University, 31 March 1976. Greenberg, J., A Benefit-Cost Analysis of Nuclear Power Applied to the GPS Mission, Report No. 76-154-1, ECON, Inc., Princeton, New Jersey, 30 September 1976.

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The next few years promise significant improvement in solar cell performance. The Violet Cell represents at least a 30 percent increase in power density with respect to conventional solar cells. Furthermore, the nonreflective cell permits further improvements that may exceed 50 percent. The electrical performance of typical laboratory-produced Violet and nonreflective cells is compared to that of a conventional satellite cell in Figure 5.8. In addition to performance, production costs and life expectancy of these new solar cells will play a large role in determining the extent to which they are used.

Power systems based on solar energy must incorporate some type of brief energy storage for eclipse and initial acquisition intervals. Batteries have been used exclusively on commercial spacecraft for energy storage. These have been the nickel-cadmium (Ni-Cd) alkaline type. They provide a high-rate, deep-discharge capability and fairly long storage life.

The typical range of performance for Ni-Cd batteries appears to be 4-6 Whr/lb.

Other advanced energy storage devices have been extensively studied and some of these may evolve into practical hardware during the 1980s. A major near-term advance in battery technology is the sealed nickel-hydrogen cell. This new cell exhibits three times the usable energy density and a fivefold increase in cycle life. Inherent overcharge and reversal protection and a simple means of determining the state of charge promise higher reliability.

A novel and potentially promising device which could eliminate batteries is an integrated energy storage and stabilization system. Advances in magnetic bearing technology and flywheel design and construction should make possible high-speed wheels with high angular momentum and large kinetic

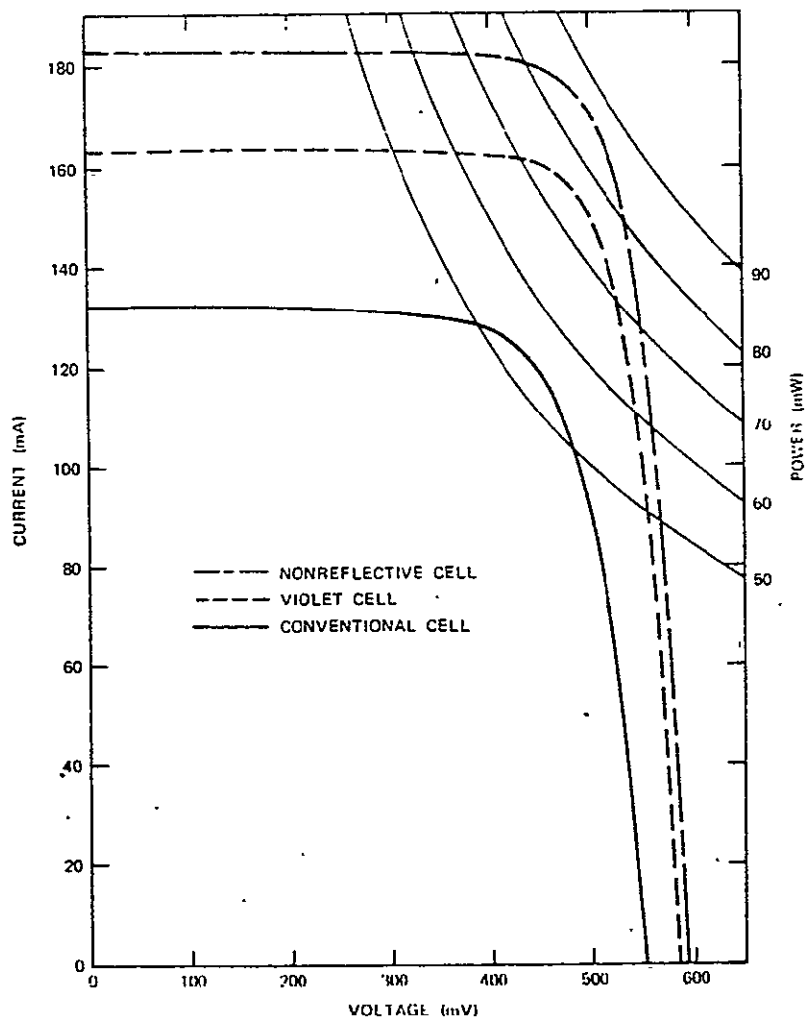


Figure 5.8 Current-Voltage Characteristics of Nonreflective, Violet and Conventional Cells

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energy storage for application to satellite attitude control and power management. For synchronous communications satellites such wheels may be useful as battery replacements or supplements with significant mass and size advantages. There are still some basic design and material problems associated with this concept. For example, alignment of the wheel axis is critical to attitude control performance. Also, power addition and extraction processes must be balanced. A long period of development and testing remains before this concept can become operationally useful.

The reaction control, or propulsion, system provides velocity increment capability necessary for satellite station-keeping. In conjunction with the stabilization system, and also possibly with magnetic coils, it may also provide the torquing necessary for attitude control. Future station-keeping requirements are likely to be similar to those of today. Existing thrusters are adequate to permit station-keeping to any arbitrary small limit which can be further tightened by correcting more frequently.

The pointing accuracy of the antennas is certain to become more constrained in any spacecraft having narrow spot beams and restriction on signal overlap into adjacent regions. These both are highly probable requirements in the 1980s. Current communications satellites typically provide pitch and roll pointing error control in the range of  $\pm 0.2^\circ$ . Perhaps an order of magnitude improvement will be necessary in some future systems. In addition, attitude sensors such as horizon sensors presently cannot measure yaw directly. More expensive star trackers will probably be required, but no major sensor developments are seen as requirements.

Torquing on 3-axis space craft for attitude changes can be accomplished by thrusters, magnetic coils (successfully operating on the RCA SATCOM) and

gimballed momentum wheels. Little additional development is needed for future systems--it is more of a case of refinement of current abilities. One unique attitude alignment problem can occur during station-keeping maneuvers because of imperfect symmetrical performance and alignments of thrusters, imprecise start and stop of thrusting and impingement of the plume on spacecraft structures. This remains a problem which will require new solutions if the improved pointing accuracy must be maintained at all times. Although catalytic hydrazine monopropellant has been generally adopted for most satellites, there are some potential innovations which are likely to be incorporated within the next five years. To improve the repeatability at low impulses, electrothermal hydrazine units may find some applications. Significant propellant mass reductions are possible by using electric thrusters. Propellant associated with north-south thrusting represents 20 percent of the initial satellite mass for seven years of inclination control. Electric thrusters could reduce this to about 2 percent, allowing a significant increase in payload mass for a given launch weight. However, there is a penalty in additional electric power which is required for thrusting operations. Thus, electric thrusters may find application in conjunction with nuclear power supplies.

#### 5.1.3 Communications Technologies

The most active area of satellite technology development is in the communications field. Primary emphasis has been on maximizing communications capability for given power and frequency spectrum. Many additional aspects of communications technology are now being pursued. These include improvements in modulation techniques, new multiple access methods, multiple beams, use of cross polarization, wider frequency spectrum utilization, on-board

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switching and signal processing, optimization of orbit spacing, and use of intersatellite links. Trends and expected developments in these areas are reviewed in the following paragraphs.

Commercial communications satellites currently operate in the 4 and 6 GHz bands. However, new frequency bands have been assigned for satellite communications in 1971 at the World Administrative Radio Conference (WARC). The two new pairs of bands are at 11 and 14 GHz, and at 19 and 29 GHz. The first pair have bandwidths of 500 MHz, similar to those at 4 and 6 GHz. These frequencies are subject to flux density limitations because presently part of the band is also used for some terrestrial services. The WARC decision of 1971 resulted in an overall available bandwidth eight times that available at 4 and 6 GHz. Decreased antenna sizes and reduced sharing aspects of these higher frequencies make the new bands very attractive. The Communications Technology Satellite (CTS), launched in early 1976, is testing the 11 and 14 GHz bands. Its objectives include a demonstration of TV transmission to various sized receiving antennas. Major subsystems being tested include a super efficient TWT, a liquid metal slip ring, and a lightweight solar array with initial power in excess of 1.0 kWe. INTELSAT V will incorporate 11/14 GHz bands beginning in the late 1970s. Next generation domestic satellites can be expected to utilize this new technology.

In addition to new frequency bands, capacity can be increased through the use of cross polarization. For example, the satellite bandwidth can be directly doubled at a given frequency by using two opposite or orthogonal polarizations. This technique is already being used in SATCOM and COMSTAR and is certain to be used on future domestic satellites because of its obvious advantages at relatively low complexity. The main testing and development

requirements in the near term relate to the effectiveness of cross polarization techniques at 11/14 GHz and 19/30 GHz under varying conditions.

A further technique to extend capabilities is called "cross-strapping". For example, transmissions to the satellite at 6 GHz (or 14 GHz) may be interchanged between 4 or 11 GHz for the down link. This appears to extend existing bandwidth but actually is likely to only provide alternative paths--not both. This approach requires increased sophistication.

More significant advances are associated with efficient modulation and access techniques. Frequency modulation (FM) continues to be used for commercial applications with frequency division multiple access (FDMA). This technique permits several FM carriers to be transmitted through a single transponder to establish communications channels. For example, FM/FDMA yields about 450 to 900 voice channels in an INTELSAT IV global beam, depending on the number of accesses to the satellite. The RCA SATCOM also used this kind of multiple access technique, and it appears that it will continue to have extensive applications into the 1980s.

Other modulation and access schemes are under intensive investigation. Undoubtedly, the 1980s will experience vast changes in bandwidth utilization and expansion of useful channel capacity. Digital techniques are beginning to have an impact on this quickly changing technology; for example, digital speech interpolation (DSI) may effect a twofold increase in communication capacity, because in a normal voice transmission the voice channel is active only 30 to 40 percent of the time. The remaining time can be used for other communications traffic.

There is a new access approach, time division multiple access (TDMA), which offers a 1.5 to 2 times increase in capacity over FDMA. TDMA is a

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technique in which several earth stations use a given satellite transponder which operates in a most efficient (saturated) mode through timed transmissions of data bursts, i.e., a time-sharing approach. Since there is no overlap of transmissions, the same carrier frequency can be used by all earth stations sharing a given transponder. This method does require digitally encoded and sampled data because of the burst mode of transmission as well as precise synchronization of the various users.

Another line of investigation which can increase capacity is the intersatellite link. This technique should be able to satisfy traffic requirements by an increase in connectivity. A significant increase in investment is associated with additional satellites, but the earth segment is not affected. The U.S. Government's Tracking and Data Relay Satellite System program (TDRSS), under NASA's direction, will provide practical testing of the operation and performance of intersatellite communications. However, commercial use of intersatellite links is still many years away and potential capacity increases are not well established.

The above communications technologies tend to be near term and do not appear to require a major development effort to insure their availability.

There are other potential technologies, such as high speed, on-board computerized beam switching coupled with multiple beams, and on-board signal processing, which imply a much larger and vastly more complex space segment. These capabilities will require substantial R&D programs to bring the technologies to the state where they will have the performance and reliability essential for commercial applications. By itself, this technology would not provide much of a new market to its developers and would not be economically attractive enough to warrant the investment risks. On the other hand, if



these technologies bring about a more simplified terrestrial system (small, low-cost earth stations), their existence would open a vast new market (but still, not necessarily beneficial to the space hardware developer).

It seems reasonably certain that somebody will pursue these new technology programs, in view of the possible economic benefits to the total system. If recent history provides any guide, ESA and Japan will be very active. Without substantial government support, there does not appear to be a mechanism nor adequate motivation to develop these new technologies for commercial application by United States space communication industry.

In summary, communications technology will experience great advances with respect to the space segment of satellite communications systems of the 1980s. The present modulation and access technique, FM/FDMA will prevail for at least three years. During the early 1980s, digital techniques and TDMA are likely to take over and continue through the 1980s. Cross polarization will be very popular for domestic systems. Other, more advanced, access on-board functions and modulation methods may well evolve in the next five to ten years if sources of R&D support for these areas are found. Yet, it is these later technologies that will make possible the next major growth phase in space communications, by making possible satellite systems that can work with many small, low-cost earth stations.

## 5.2 Space Communications Cost Estimates

In comparison with other industries, satellite communications systems require high levels of capital investment. It is estimated that approximately ten times the average of all industrial capital investment is required for communications operations. The investment cost for space communications systems is the sum of space and earth segment costs. From the viewpoint of the user, in addition to the hardware costs, additional expenditures are required for the programming and other software. Space segment costs are

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comprised basically of R&D, spacecraft, launch and control station (telemetry, command and control) costs.

Depending upon the size and specific nature of the program, previous R&D data base, and new technology requirements, typical estimates for R&D costs would be \$20 to \$50 million (1977 \$) for a moderate effort, and \$100 million (1977 \$) for a larger program. A breakdown of the typical R&D effort is:

	<u>% of Total R&amp;D Budget</u>
Design and Development	50.0
Test (thermal, mechanical)	2.5
Engineering Model	10.0
Prototype and Flight Model(s)	<u>37.5</u>
	100.0

Launch costs include the cost of the launch vehicle and fees paid for launch facilities and services plus insurance, if any. Typical launch costs by NASA for a commercial customer are:

<u>Vehicle (including AKM)</u>	<u>Useful Payload in Orbit</u>		<u>Approximate Cost (\$, Millions)</u>	
	<u>pounds</u>	<u>kg</u>	<u>1973</u>	<u>1976</u>
Delta 2313, 2614, 2914 3914	450-700 990	204-318 450	8-8.5 9.8	12 15
Atlas Agena Centaur	1100-1500	499-681	12-15 18	18-22 26
Titan Types	2100-3400	953-1544	20-30	30-40

Earth station costs typically include expenses for equipment, physical plant and terrestrial interconnections to users from the earth station. Terminal equipment currently costs about \$4 to \$8 million (1977 \$) for large international stations and from \$250,000 to \$1.2 million (1977 \$) for smaller stations. Earth station costs for buildings and terrestrial interconnections

depend on location, size, etc. Location (accessibility) can be a very significant factor in the installation and operating costs, especially where remote sites are concerned.

Spacecraft costs are rather difficult to generalize because of the wide variety of satellite configurations, but tend to average around \$10 million per commercial spacecraft, including R&D.

From these very basic costing elements, we can derive a number of roughly \$100 million minimum as representative of the estimated initial cost of financing a satellite communication system. Initially, it will be the customer nation's financial stability and status which will or will not accommodate the financing for the satellite system. This is a commitment which the majority of the world's nations cannot irresponsibly enter because of internal competition for capital investment, commercial and social developments, and other high priority national programs. Space communications systems applications will in many instances have to wait for development of understanding of the interaction of communications within their application, particularly all forms of education and economic development.

### 5.3 Economic and Technical Potentials for New Applications

During the next 25 years considerable activity in global space communication systems can be anticipated. However, it is not sufficient to simply deduce the extent of possible bounds of a space communications market; this market's future applications, which will demand technology more sophisticated than that employed operationally and experimentally today, must also be explored. Implicitly this assumes that the current experimental efforts of Canada, Japan and the European Space Agency, all undertaken with substantial technical inheritance from the U.S. space communications industry or NASA, will

generate results which will be shared with some part or all of the U.S. space communications industry.

There are no "guarantees" that such sharing will occur in a manner which would benefit U.S. space industries on a quid pro quo basis! However, it is also possible that the U.S. could utilize and build upon foreign R&D results (if available), as other nations have done with our technologies.

Communication service delivery is concerned with providing communications where it is geographically needed, with qualities appropriate to the applications, at the least possible cost to the users.

The full potential of such service will only be realized when the communications capacity in a transmission beam can be optimally matched to the requirements of the application. Ultimately this requires exploration of techniques and trade offs using allocated regulated bandwidths, multiple use of these bandwidths, on-board signal power generation, multiple beam generation and shaping, access and beam shifting, bandwidth compression and digital techniques and on-board computer controls.

The downlink available bandwidth increases from 0.5 GHz at 4 GHz to 10 GHz at 200 and 265 GHz but there are numerous gaps in the technology at most frequency bands higher than 4 GHz.

Communications technology is extensively developed in the 6/4 GHz band because terrestrial equipment has operated at these frequencies for some time. However, space and terrestrial operations at 6/4 GHz can interfere, and for this reason, constraints have been placed on space power flux densities. Operational systems are shifting to 14/12 GHz where current regulation allows unconstrained power flux densities, which will then permit space operation at 14/12 GHz without interference into regions where terrestrial

communications are most dense. Based upon extensive statistical data on background noise, it would appear that a 10 db power margin should provide satisfactory operation most of the time except for certain regions such as the East Coast of the United States. In nations without extensive terrestrial microwave communications, 6/4 GHz could be used at a higher flux density power than in most industrial nations, with frequency reuse as needed to fulfill capacity requirements.

As communications demand varies within an illuminated geographic region, such demand can be accommodated by creating beams that subdivide the geographic region either through beamwidth agility or by generating multiple beams. Thus, if a space system design can incorporate flexibility in beam generation, and in optimizing bandwidth and power in each beam, then a space communication system can have a modular capacity for growth. This can be compared to a terrestrial telephone network's growth modularity by which the investment cost per unit of capacity decreases as the well-utilized capacity increases.

As a consequence of this development ground receiving terminals can be reduced in complexity and investment cost as more system control is exercised by the space segment. This also permits one to resolve the effectiveness of space communications relative to other communications technologies and to optimally utilize the geosynchronous arc for global communications use.

Interference between contiguous illuminated geographical areas must be avoided by design constraints on the beam shaping and sidelobe power generated or by frequency discrimination. Interference amongst satellites is controlled by the physical separation of the operating satellites in relationship to the beam characteristics of the earth terminal antenna or by frequency discrimination.

Beamshaping to a limited degree has been used in a number of satellites, including INTELSAT IV-A, ANIK, WESTAR, SATCOM and COMSTAR. ATS-6 has generated multiple beams from a single reflector. More extensive experimental programs investigating multibeam generation from a single aperture have been conducted by Lincoln Labs and by Lockheed. The first operational spacecraft to employ a flexible multiple-beam antenna will be USAF's DSCS-III, using military frequencies, expected to be launched in 1978. In the United States multiple beam communication requirements are likely to evolve during the next ten or fifteen years, for applications such as ATT interconnections amongst major switching centers, post office mail interconnection between major post offices, data distribution systems among major corporate terminals, interconnections among major computer data bases for governmental and corporate activities. These may require nonoverlapping spot beams. The application of this research may be long-term, lasting perhaps 25 to 50 years. Without the expenditure of significant R&D funds, this need of the industrialized nations will be fulfilled at a very slow pace. It is unlikely that U.S. industry will undertake this R&D without federal government support. Thus, if the benefits of these technologies are to be realized, it will be necessary for the U.S. government to initiate R&D support in these areas, and perhaps to demonstrate the practical applications of these technologies through the continued use of R&D spacecraft such as the ATS series.

#### 5.4 Foreign Activities and Plans

In addition to the United States, various nations are investigating space communications potentialities under governmental sponsorship. The advantage to all nations will be better understanding of when, how and which space communications will be most applicable and effective for them.

Tables 5.1 through 5.5 summarize the levels of spending for various space applications for FY 1974 through FY 1977 on a domestic and worldwide basis. While one sees that the United States is the dominant factor in space communications, the role of NASA (measured by funding support) has become insignificant.\* It is virtually certain that, if the trends shown in these tables continue, Canada, ESA and Japan (governments and industry) will actively challenge the United States for the next generation of space technology. Table 5.5 provides one indication of relative activities by key competing nations.

Several foreign governments (notably France, Germany, Japan) make a practice of exerting influence on their industries where competitive procurements are involved, especially internationally. In essence, those governments study the overall national benefits and impacts that are associated with a potential procurement. Among the factors considered are: technology buildup, tax returns on incomes derived, related unemployment/welfare costs, dollar availability in local markets to procure other goods/services, resulting marketable products, balance of trade, and the amount of government "investment" necessary to insure a "win" by their competing industry. If the study results are favorable the government may underwrite a portion of the costs involved to "keep the business at home." This subsidization may take many forms, the most obvious being a government funded development program. The U.S. government sponsors considerable industrial R&D, but with the outward objective of developing new technologies with

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\* Estimate of Total Worldwide Space Applications Expenditures for Civilian Uses, ECON, Inc., Princeton, New Jersey.

Table 5.1 Total Identified Worldwide Space Applications Expenditures				
Application Area	FY 74	FY 75	FY 76 <sup>**</sup>	FY 77 <sup>**</sup>
Communications	997.3	1221.5	978.1	1079.2
Meteorology	231.0	274.6	213.8	218.2
Ocean Surveillance	259.0	291.7	125.6	163.1
Earth Resources	95.0	86.0	91.3	109.4
Space Material Processing*	3.0	60.6	115.7	120.4
<sup>*</sup> All Spacelab expenditures included in Space Materials Processing <sup>**</sup> U.S.S.R Data Not Available for These Years				

Table 5.2 Total Identified U.S. Space Applications Expenditures				
Application Area	FY 74 <sup>**</sup>	FY 75 <sup>**</sup>	FY 76 <sup>**</sup>	FY 77 <sup>**</sup>
Communications	299.0 (22.1)	368.9 (12.0)	593.3 (10.0)	840.6 (12.5)
Meteorology	121.6 (35.0)	138.4 (42.1)	160.4 (42.7)	185.2 (45.9)
Ocean Surveillance	56.6 (18.5)	64.0 (15.6)	125.6 (20.8)	163.1 (37.1)
Earth Resources	95.0 (88.4)	86.0 (66.3)	91.3 (67.7)	88.0 (88.0)
Space Material Processing*	3.0 (3.0)	4.6 (4.6)	5.7 (5.7)	10.4 (10.4)
<sup>*</sup> All Spacelab expenditures included in Space Materials Processing <sup>**</sup> Total Funding (NASA Funding)				



Table 5.3 Total Identified Foreign Space Applications Expenditures Other Than Those of the U.S.S.R.

Application Area	FY 74	FY 75	FY 76	FY 77
Communications	350.3	374.1	384.8	238.6
Meteorology	7.9	55.0	53.4	33.0
Ocean Surveillance	--	--	--	--
Earth Resources	--	--	--	21.4
Space Material Processing*	--	56.0	110.0	110.0

\* All Spacelab expenditures included in Space Materials Processing

Table 5.4 Total Estimated Space Applications Expenditures of the U.S.S.R.

Application Area	FY 74	FY 75	FY 76	FY 77
Communications	348.0	478.5	--	--
Meteorology	101.5	81.2	--	--
Ocean Surveillance	202.4	227.7	--	--
Space Material Processing	--	--	--	--

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Table 5.5 Foreign R&D Programs With Flight Prior to End of 1978  
(Circles Signify Developed by Foreign Companies)

	Key New Spacecraft Technologies for Operational Missions of 1980s	Canada	Europe		Japan		Foreign Program Better or Earlier Than on Any U.S. Satellite
		CTS 1976	SYMPHONIE 1974	OTS 1977	MAROTS 1977	C SAT BSE 1977 1978	
Spacecraft Platform	• High DC Power	1100W	300W	800W	800W	300W 1000W	Yes, for low-cost THOR-DELTA*
	• Lightweight Subsystems - Solar Array - Batteries - High ISP Stationkeeping		(X)	(X)			Uncertain** -- Yes (provisionally)***
	• 3-Axis Platform	(X)	(X)	(X)	(X)	X	No
			Bi-Prop	Bi-Prop			
New Frequency Bands	• KU-Band Tubes	200W		20W		100W	Yes (in each)
	• KU-Band Transponder	(X)		(X)		X	Yes (in each)
	• Bands Above KU (K, Lasers, etc.)					X	Yes (30/20 GHz)
	• L-Band				(X)		No (about same)
High Capability Communication Payloads	• Deployable Antennas						No (U.S. ahead; ATS-6 30')
	• Multi-Beam Antennas						None (U.S. or foreign)
	• Space Switchboards						None (U.S. or foreign)

\* Largest U.S. THOR-DELTA satellite is 700 Watt RCA SATCOM (all BOL power).

\*\* U.S. rollout arrays are lighter (but not planned to fly at synchronous orbit).

\*\*\* LES 8 U.S. military satellite electric propulsion offers greater potential.

broader applications to numerous projected national (government) requirements--not to provide a given private industry with special competitive advantages.

Competition to the United States in space segment fabrication, geosynchronous launch and tracking control exists in the U.S.S.R. The U.S.S.R. plans to provide launchings for foreign nations (Sweden, India). Japan and ESA<sup>\*</sup> are moving toward similar capabilities.

Launching capability may ultimately be developed in four or five competitive organizations but the United States should maintain considerable competitive leverage especially with the advent of the Shuttle and Tug. The projected price of a typical communications satellite launch could drop to \$7 to \$8 million, with a 76 percent loading of the Shuttle, in the early 1980s.<sup>\*\*</sup> While nations may have other launch options available to them in this time period, economic advantages associated with the Shuttle and specialized configuration design for the Shuttle should favor U.S. industry.

As a whole the developing nations, some 112 of them, have considerable unsatisfied telecommunications demand, generally viewed as a telephone demand. Telephones are primarily used by government, business and the professions. During the next decade, with the expected growth in GNP/capita, some 320 million telephones are expected to be installed in both industrial and developing nations. At an investment of \$1000 per telephone, about \$40 billion annually will be needed. Tariffs can be established to fully cover costs and to generate substantial surpluses for reinvestment because demand

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<sup>\*</sup> ESA has a request by India for launch in 1980.

<sup>\*\*</sup> Aviation Week and Space Technology, May 31, 1976.

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far exceeds supply. Return on investment can be as high as 50 percent. Historically speaking, however, no long-term growth can be sustained at more than 15 percent per annum, and economic replacement of switching can occur only every ten to fifteen years. However, telephone network expansion should not necessarily be construed as a top national investment priority. Alternate investment in sewers, electric power, education or manufacturing may be more politically expedient. Where telephone network growth has been undertaken as a national objective, standardization (which is basic to economic telephone networks) leads to bulk supply and to the establishment of national industries, as in Argentina, Brazil and India, and to a lesser extent in Pakistan, Iran, Israel, Egypt, Malaysia, Thailand, Singapore, Colombia and Venezuela. As telephone usage expands to about 0.5 million, historically, a nation finds it advantageous economically to develop its own industry, including switching equipment. This tends to provide employment as economic growth progresses. As a basic communication activity, the telephone network development is fundamental to most developing nations. The telephone is an extremely simple terminal to use, even for the illiterate, and this simplicity is extremely attractive. The majority of developing nations will therefore invest in telephone communication systems, most generally as a basic backbone communication system of a series of local networks with the minimum of long distance domestic links. The principal problem for these nations is that of defining traffic demand since there is no historic data. They must therefore create their usage history and be concerned with securing financing for telephone modernization and development.

The petroleum exporting nations are generally possible exceptions since they have or can easily acquire the finances for telephone development and

for space communications simultaneously. Today many of these nations are, in fact, already involved in space communications.

In the interest of improved basic understanding of the various inter-relationships, studies are being conducted in Sweden, United Kingdom and Chile on:

- Interdisciplinary aspects of telecommunications relating to telecommunications and regional development
- Conceptual communication frameworks and effectiveness
- Accessibility and costs of communications.

These studies are concerned with the essential service characteristics of communications, and how and to what extent they support the human function. In particular they indicate to some degree how users can be organized to benefit from telecommunications potential as an economic production factor and hence to identify useful innovative research and development and marketing processes.\*

#### 5.5 Conclusions Concerning Long-Term Systems Applications and Requirements.

Three factors emerge as important in the consideration of long-term trends. These are:

- Changing user needs and their effects upon communicating technology requirements
- The effect of the Space Shuttle on spacecraft design and launch costs
- The diminished stature of NASA support to communications R&D and the concurrent support of high technology advanced communications satellite programs in Canada, Europe and Japan.

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\* Interdisciplinary Aspects of Telecommunications; Björa Wellenlus, Universidad de Chile, World Telecommunication Forum, Technical Symposium, Geneva, October 1975, Annex, p. 1.1.4.1.

The trend of user needs appears to be toward systems that will provide the capability for direct user-to-user communications as opposed to the trunking systems in use at the present time. Direct user-to-user communications implies the need for multiple access, higher radiated power, new transmission frequencies, multi-beams, and switching and processing on-board the spacecraft. These techniques lead to the possibility of small, low-cost earth stations, including mobile stations. In the evaluation of long-term trends it is important to recognize that communication satellite R&D programs in Canada, Europe, and Japan have taken the lead in development of high radiated power systems at new transmission frequencies.

The trend toward small fixed and mobile earth terminals introduces technical considerations that have not been dealt with in previous systems. For example, low-cost earth terminals with small fixed antennas will probably not cause interference problems with adjacent stations. However, low-cost mobile stations will probably use omnidirectional antennas and will have to be displaced in frequency from fixed stations in order to minimize the possibility of interference.

At the present time, the United States is the acknowledged world leader in development of operational, domestic and international communications satellite systems. The present state of technology in these systems is mainly attributable to research and development funded by NASA in the decade between 1963 and 1973. Since 1973, the role of NASA in space communications has significantly declined. In fiscal year 1974, NASA funding constituted about 7 percent of all U.S. space communications expenditures. By fiscal year 1977, the NASA role had decreased to approximately 1.5 percent. In the same time period, during which the role of the U.S. government in the support of

space communications R&D has decreased, Canada, Europe and Japan have undertaken major advanced technology space communications programs. The technology emphasis in these programs has been the development of high powered systems that are capable of communicating in frequency bands that may meet future user needs. While the United States remains in a dominant role as the supplier of operational systems, the decreasing U.S. R&D base, the absence of a systems oriented communications satellite R&D program in the United States, and the advent of strong communications satellite systems R&D programs in Canada, Europe and Japan opens to question the continuation over the long term of a dominant role by U.S. industry in this field.

The Space Shuttle will become operational in the 1980s and will probably replace most of the present expendable launch vehicle systems. If the expected reductions in launch costs are achieved by the Space Shuttle, the reduced costs of inserting a satellite into orbit could accelerate the development of new space communications systems. When full operational capability of the Space Shuttle and Tug is achieved, including on-station repair or recovery from orbit, further reductions in the costs of space operations may be achieved. The U.S. aerospace industry will probably lead foreign industry in the design of spacecraft to use the Space Shuttle. In this case, the U.S. aerospace industry could achieve a significant technological and cost advantage. However, the exploitation of this advantage will require the investment of R&D funds to develop communications satellite systems that fully utilize the ultimate physical and operational capabilities of the Space Shuttle and Tug. It should be recognized that the U.S. government will retain an additional degree of control in the area of rate setting for the use of the Space Shuttle. Preferential rates for the launching of satellites

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built in the U.S. could help provide a competitive advantage to the U.S. aerospace industry.